

Wood Quality... Impact on Product Yields, Grades and Values

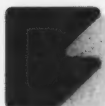


Forest Practices Branch
Ministry of Forests

Canada

CANADA-BRITISH COLUMBIA
PARTNERSHIP AGREEMENT ON
FOREST RESOURCE DEVELOPMENT:
FRDA II

BC



**Forintek
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Big or Small Trees, Fast or Slow Growing Trees?



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BC Forestry
Continuing
Studies
Network



Wood Quality... Impact on Product Yields, Grades and Value
INTRODUCTION, HISTORICAL TRENDS

10

INTRODUCTION AND HISTORICAL TRENDS

The official title of this workshop is **WOOD QUALITY...IMPACT ON PRODUCT YIELDS, GRADES AND VALUE**. If we were forced to condense the theme of this workshop into a brief "grandmother's-executive- summary", the following would be good one: what would you rather grow, **BIG OR SMALL TREES?...FAST OR SLOW GROWING TREES?**

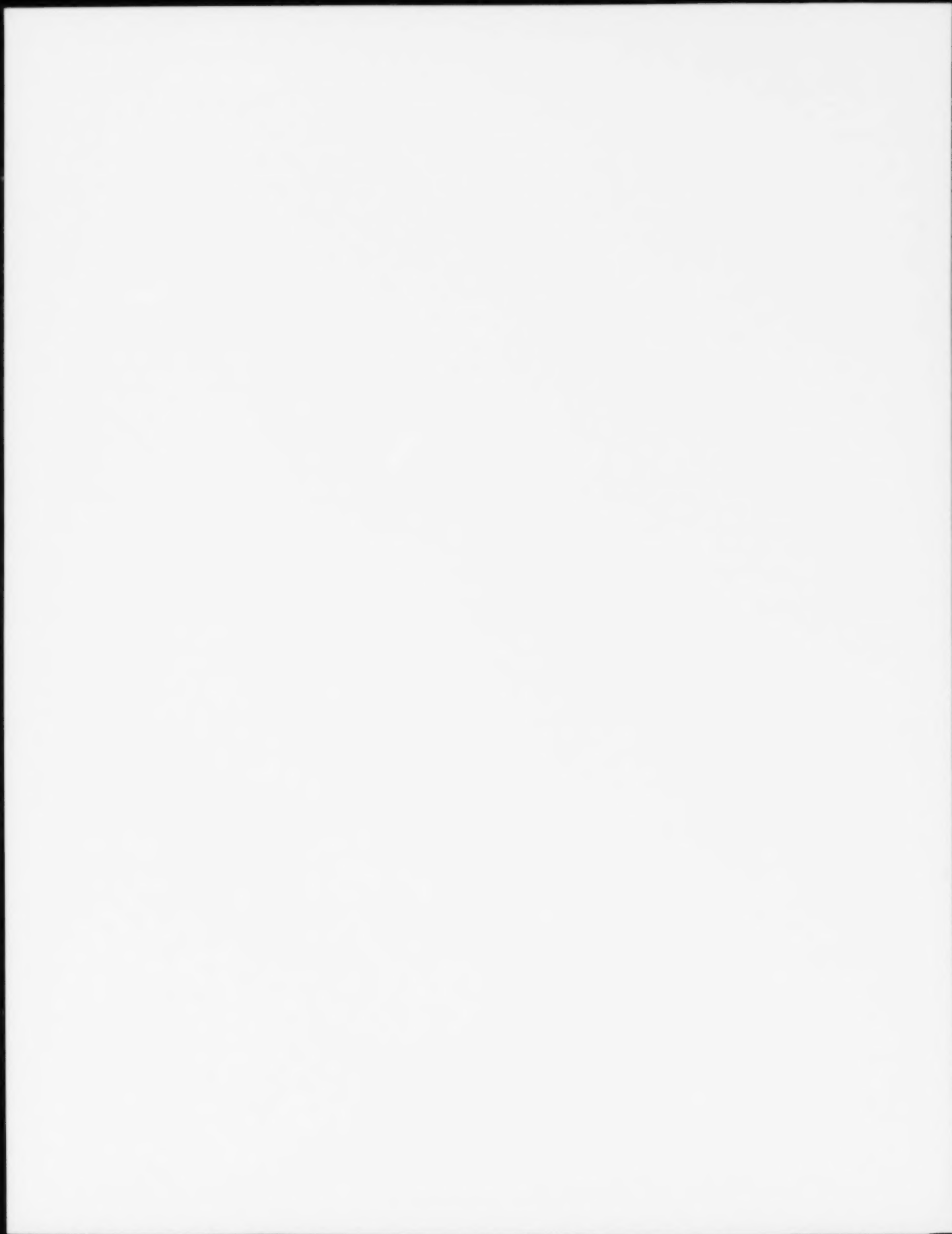
Funding for developing this workshop was provided by the Canada-British Columbia Partnership Agreement on Forest Resource Development: FRDA II – a five-year (1991–96) \$2000 million program, cost-shared equally by the federal and provincial governments.

I would like to thank my friends and colleagues not only for the financial support, but also for their help and suggestions in putting together this workshop: Mr. Dean Mills, Canadian Forest Service, Victoria, BC, Messrs. Frank Barber and Ralph Winter, Forest Practices Branch, BC Ministry of Forests, Victoria, BC.

We are grateful to Ms. April Anderson, BC Forestry Continuing Studies Network, for the logistics of arranging four sessions.

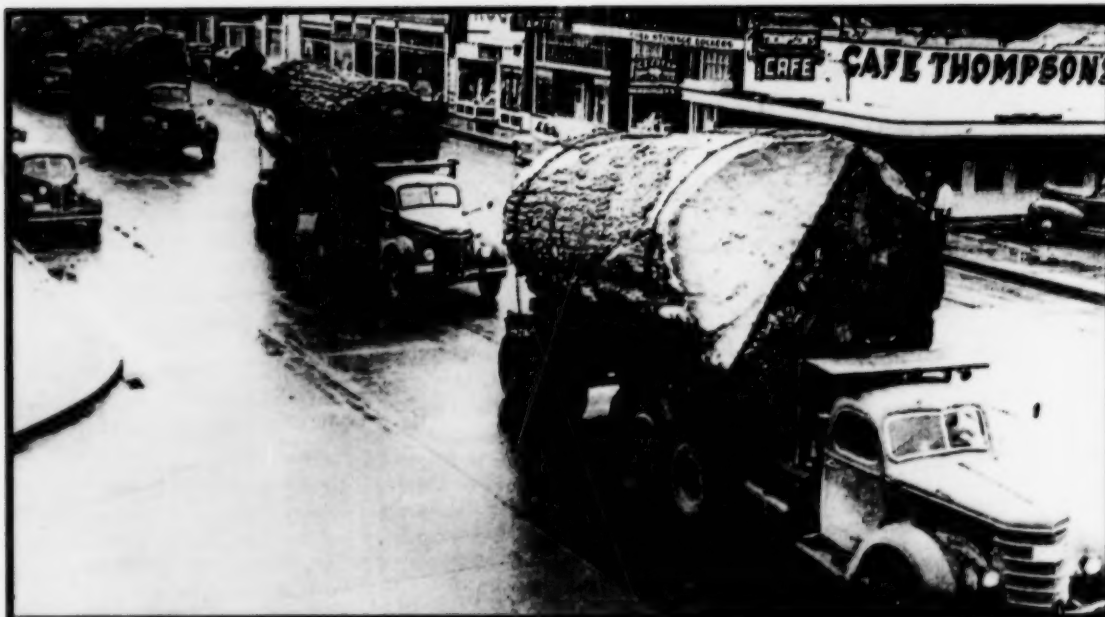
The presentation material consists of **Instructor's Notes** and a *Student's Workbook*. This text is part of the Instructor's Notes; accompanying each overhead, these are the key points to be made in a verbal presentation. The Student's Workbook contains reduced black-and-white reproductions of each overhead (two to a page) for note taking, and a selection of technical reports and publications.

This one-day workshop grew out of Forintek's resource evaluation research, showing that wood quality attributes important to primary and secondary manufacturers are determined to a large extent by the circumstances in which trees grow. This means there is an important role for foresters in linking stand management practices to end-product requirements.

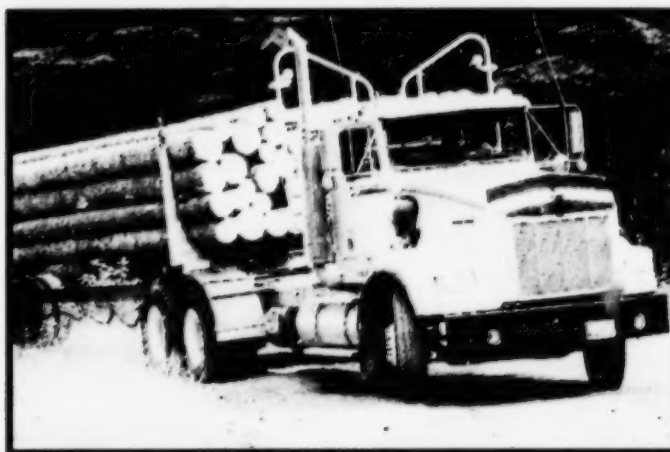


Although the course was designed for personnel involved in planning, prescribing or implementing silvicultural activities in the field, others would benefit as well (foresters, forest educators, mill managers, marketing experts, etc.). The course is structured around the following headings:

- Introduction and historical trends
- Global wood supply and wood demand trends
- Brazil and New Zealand
- Tree growth and tree physiology
- Wood structure and fibre morphology
- Relative density of wood
- Juvenile wood, crown-formed wood
- Compression wood
- Shrinkage of wood
- The concept of "free" and "bound" water
- Douglas-fir Task Force
- Lodgepole Pine Task Force
- Machine Stress Rated (MSR) lumber
- Lodgepole pine confirmation study
- Western hemlock basic wood properties
- Composite products, summary and conclusions



Then & Now



Wood Quality... Impact on Product Yields, Grades and Value
INTRODUCTION, HISTORICAL TRENDS

OVERHEAD 2

Historical Perspective – Then & Now

Some things change, some things don't...

Large old-growth logs are no longer the staple for British Columbia's forest products industry. Instead, the industry had to learn to adapt to the processing of smaller stems, and increasingly to the processing of young and small second-growth logs.

For example, 40 years ago, coastal utilization standards were shocking; logs smaller than 40 cm (16 in.) small-end diameter could be left behind in the woods (in other words wasted) without penalty. This went on to the late 1960s when close utilization standards were introduced with the stroke of a pen; the small-end diameter was reduced to 10 cm (4in.).

This was the advent of the Interior sawmilling industry, and more importantly the "rehabilitation" of lodgepole pine. With the "fall-down effect" and fibre shortages, industry had no choice but adopt a broad range of new technologies. This included computerized controllers, electronic and optical scanning devices, thin-kerfed saws, lumber drying, finger jointing, edge-gluing, composite products, etc.

(Before one gets into a self-righteous frame of mind, one must remember that if one were in the logging/sawmilling business of that time, one would have had to do exactly the same to stay in business.). On the other hand, reliance on the internal combustion engine, as the primary means of log transport, has changed very little (except for safety and efficiency).



OVERHEAD 3

This overhead illustrates "then & now" as well, with one major wood quality attribute often overlooked; this Douglas-fir tree was 2.5 m diameter at breast height, it was about 850 years old, and it was sound to the pith. The lower 30 m portion of the stem was free of branches. The tree was so well balanced that the loggers had to use a hydraulic jack to push it over at the time of felling. Bark was up to 25 cm thick, which the loggers stripped from the bottom log for firewood (outer dead bark of Douglas-fir burns with a glowing intensity for a long time, sometimes melting the iron grill that is used in fireplaces).

They could not make lumber from these logs, they could not peel them for veneer.....they were chipped for pulp because of excessive **spiral grain**. Why is spiral grain so bad? From the solid wood products perspective, excessive spiral grain in logs results in excessive slope of grain in lumber, hence weak lumber. In panel products, raised grain is impossible to finish through planing or sanding.

Each overhead shown has a main message to deliver (as stated above). In addition, there must be a number of qualifications the instructor should be prepared to make, as follows in this example:

A common spiral-grain pattern in our conifers is one in which grain in the first annual ring is parallel to the pith, but in immediately following rings a left-hand spiral (S) develops. This increases to a maximum, then diminishes to zero, and finally becomes increasingly right-handed (Z) with great age, as shown in this illustration.

What causes spiral grain? According to a morphogenetic explanation "the arrangement and orientation of cambial cells very largely predetermines the relative position and arrangement of the various xylem derivatives, and hence the grain angles in wood". Environmental and silvicultural conditions are not well studied and documented, however, the author has observed extensive spiral grain in very old trees (>500 years), and in upper-elevation timberline environments while hiking in the mountains.

Some facts:

- Northern trees do not reverse their spirals when grown in the southern hemisphere. Note left- hand spiral in the young radiata pine on the RH side of this overhead (this tree is about 10 years of age and the spiral grain is close to 30 degrees).
- Spiral grain in lodgepole pine utility poles contributes to sapwood rot because water gets trapped from rain more readily than in straight (vertical) grained poles.
- Twisting of utility poles in service is definitely correlated with spiral grain. Because of internal grain structure, poles with RH spiral were more stable than straight-grained poles.
- In a study of western larch, researchers found a correlation between the ratio of live-crown length and spiral grain; trees in open stands had LH spirals (with long crowns), while trees from dense stands (with short crowns) had RH spirals. These observations were made on stem surface only (difficult to do).

Where will they come from

**Wood and other raw materials
for the 21st Century**

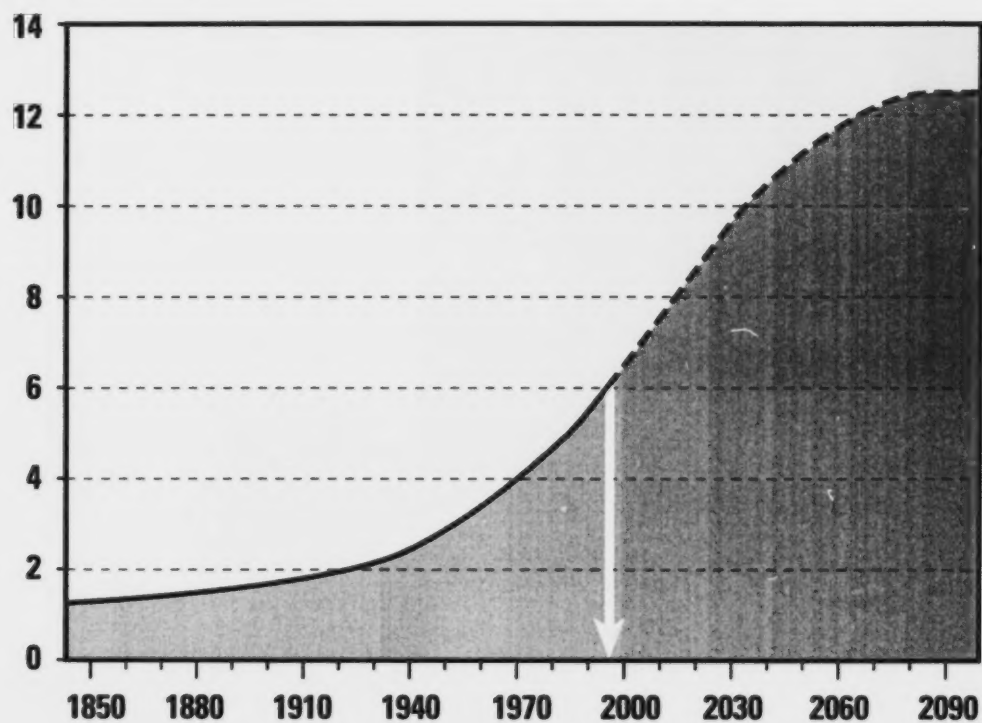


OVERHEAD 4

GLOBAL TRENDS

World Population 1850 to 2100

Population (Billions)

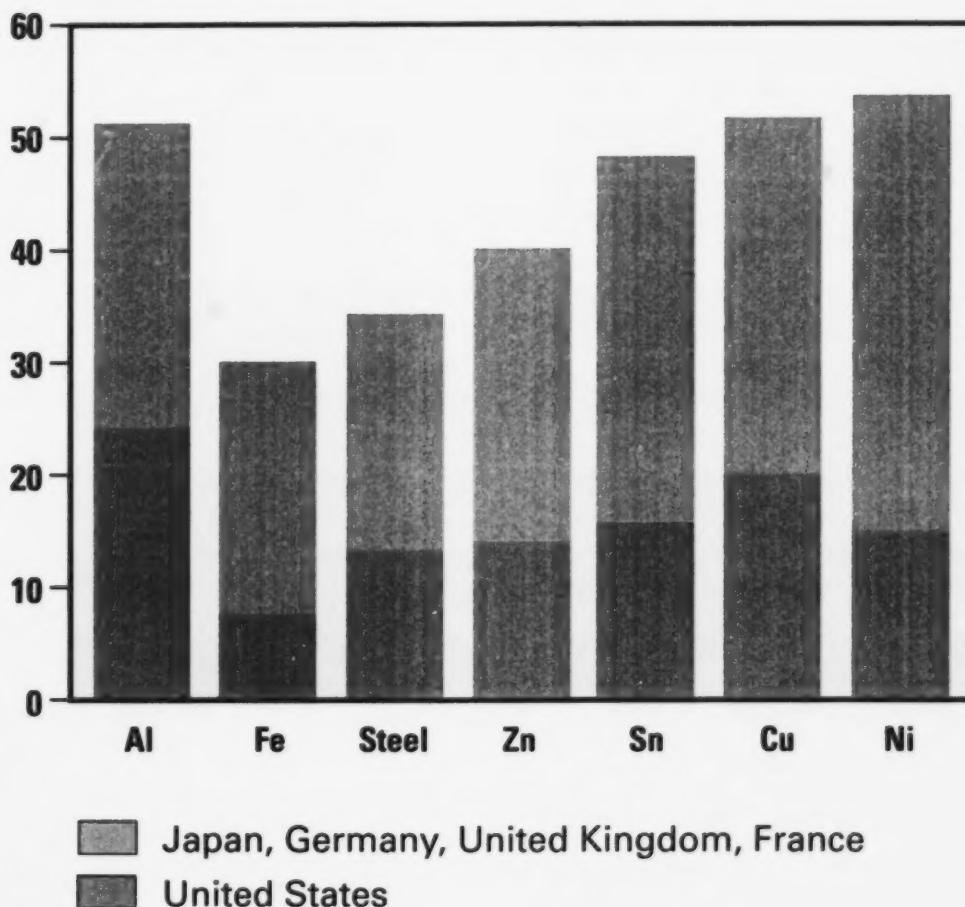


OVERHEAD 5

The greatest threat to global well-being is the unprecedented population explosion. Currently, the net population gain is 3 people per second. This means that in one minute from now there will be 180 more people on Earth. By the time we take a coffee-break, in one hour, there will be 10 800 more people... in 24 hours 259 200...by the end of the month 7 776 000...and by the end of the year 93 600 000!!!!!!!!!!!!!!!!!!!!.....They will need food, clean water, clothing, and shelter.

Global Consumption of Raw Materials by 10.3% of Global Population

Global
consumption (%)



OVERHEAD 6

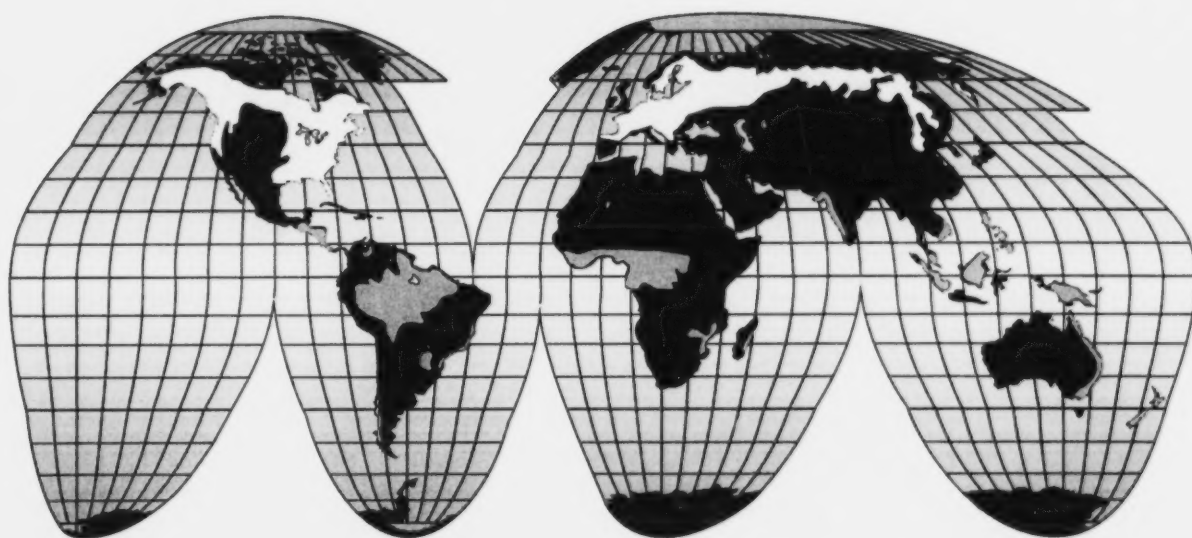
Twenty-two percent of the world's population lives in the **developed nations**, who use more than half of all global resources and energy. If all the inhabitants of planet earth enjoyed our high standard of living, we would need another 4 planet earths to sustain us!

Just consider the global consumption of **aluminum, iron, steel, zinc, tin, copper, and nickel**;.....about 50% is being consumed by only 10.3% of globe's population (please note the USA share of the pie!).

It is noteworthy that we will never exactly run out of our **limited global resources**, instead, we will have to go farther, deeper, and higher to get our raw materials. For example, if we look at the average global copper ore today, we have to mine 8 times more ore than we did in the late 1800s, to get the same amount of copper. Of course this adds to air pollution (not only in mining and transport, but also in smelting) and to the greenhouse gases.

In the future we definitely have to do more with less!!!!!!!!!!!!

Our Forests



- ☐ Temperate coniferous and mixed forests
- ☐ Tropical rain forests

OVERHEAD 7

When we look at the global forest cover map, a number of shocking realities emerge:

First, there is a lot of land area that is not forested.

Second, there is about a 50–50 split between the northern (Boreal) forest and the equatorial rain forest.

Third, all of the Boreal Forest cover is north of the 49th parallel, the USA–Canada border.

Fourth, there is no Boreal Forest equivalent in the southern hemisphere. In fact, arable land mass, south of the 49th parallel in the southern hemisphere, is less than the size of BC.

Not so obvious is that only one half of the very dominant green forest cover in Canada is capable of sustaining commercial forestry.

If we look in our own backyard, there is very little commercial forestry north of the BC–Yukon border (the 60th parallel). This dividing line dips even further south in the vicinity of Hudson Bay and James Bay.

Anticipated changes in the global fibre supply in the next 10–20 years:

Increases—USA NE (abandoned farmlands have some poor quality oaks), Chile, Europe, Scandinavia, and New Zealand.

Decreases—Pacific NW, USA SE (hottest housing starts), all of the equatorial rain forests (because of environmental pressures), Baltic states (overharvested in the recent past because of the hunger for currency).

Wildcards—Siberia and Japan. Siberia is large and has very harsh climate and very poor infrastructure. Japan has a lot of forests, but it is cheaper for them to buy our wood. In addition to their very high wages, logging and sawmilling is seen by their young as the “four-D job”: Dark, Dirty, Dangerous, and probably Demeaning.

Unfortunately, there are no hidden forest treasures out there. We are it! The Pacific Northwest is the best timber growing environment on the planet, particularly when we consider both quantity and quality.



**Wink Sutton holds
"The Wedge";
a 1.8 litre piece
of wood that
represents the
average amount
of wood used
each day by each
person on earth.**

(Based on FAO figures: $\frac{\text{total wood harvested}}{\text{population of earth}}$)

OVERHEAD 8

According to the Food Agriculture Organization (FAO), every person uses 1.8 litres of wood per day, as Dr. Wink Sutton reminded us so eloquently, not long ago. Of this daily allotment, 80% is used for cooking and heating in the underdeveloped nations (about 78% of the world's population). Only 20% is used industrially for building houses, making furniture, producing paper products, etc. In the developed nations, 75% of the wood is used industrially, and 25% is used for heating and cooking.

A number of factors must be considered to put these numbers in the proper perspective. Although in the developed nations the per capita wood use is about 3–5 times more than the global average, the **net population gain** is near zero in these countries. Poor nations don't have the ability to buy/pay for our wood.

There are two extreme views; "the Chicken Little, the sky is falling" and "the technology will solve any problem, there is plenty of fibre". Most likely the truth lies somewhere in the middle.

A Contrary View....

- **Population growth is in developing countries**
- **Fuelwood needs will not increase**
- **Less developed countries do not favour wood construction**
- **Engineered wood, wood preservation treatments**
- **Technology is improving yield from raw material**
- **Substitution effect**
- **Plantation effect**

OVERHEAD 8A

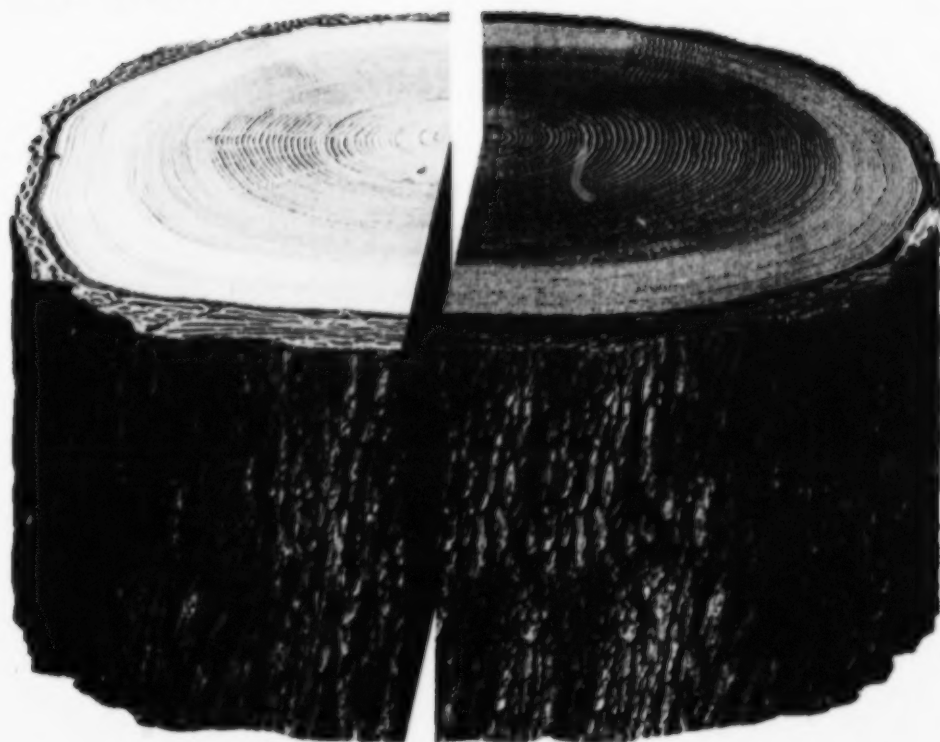
A Contrary View.....

- Population growth is in the developing world, where per capita consumption is small.
- Fuelwood needs will not increase because fossil fuels are cheap and abundant.
- Less developed countries (LDC) do not favour wood construction (equated to peasant status). When incomes increase, brick and concrete is preferred (e.g., Koreans did historically live in wooden houses, war and the devastation of their own forests resulted in the conversion to concrete as the basic building material. Until not long ago, a Korean house had to double as a bomb shelter as well.
- Engineered wood, wood preservation treatments, etc. are reducing world demand for construction (by using less wood on one hand, and having a much longer service life on the other).
- Technology is improving yields from raw material
 - greater lumber recovery/log
 - residues are being used in boards and panel products
 - high-yield pulps (TMP, CTMP, etc.)
- Substitution effect
 - electronic for printed page
 - non-wood (kenaf, corn, straw, hemp, etc.) for fibre
 - non-wood (steel, vinyl, etc.) for house/industrial construction
- Plantation effect
 - industrial wood needs have increased by 100 million m³/decade between 1960–1990
 - planting 250 000 ha. of new Eucalyptus each year would meet this demand (with 40 m³/ha/year)

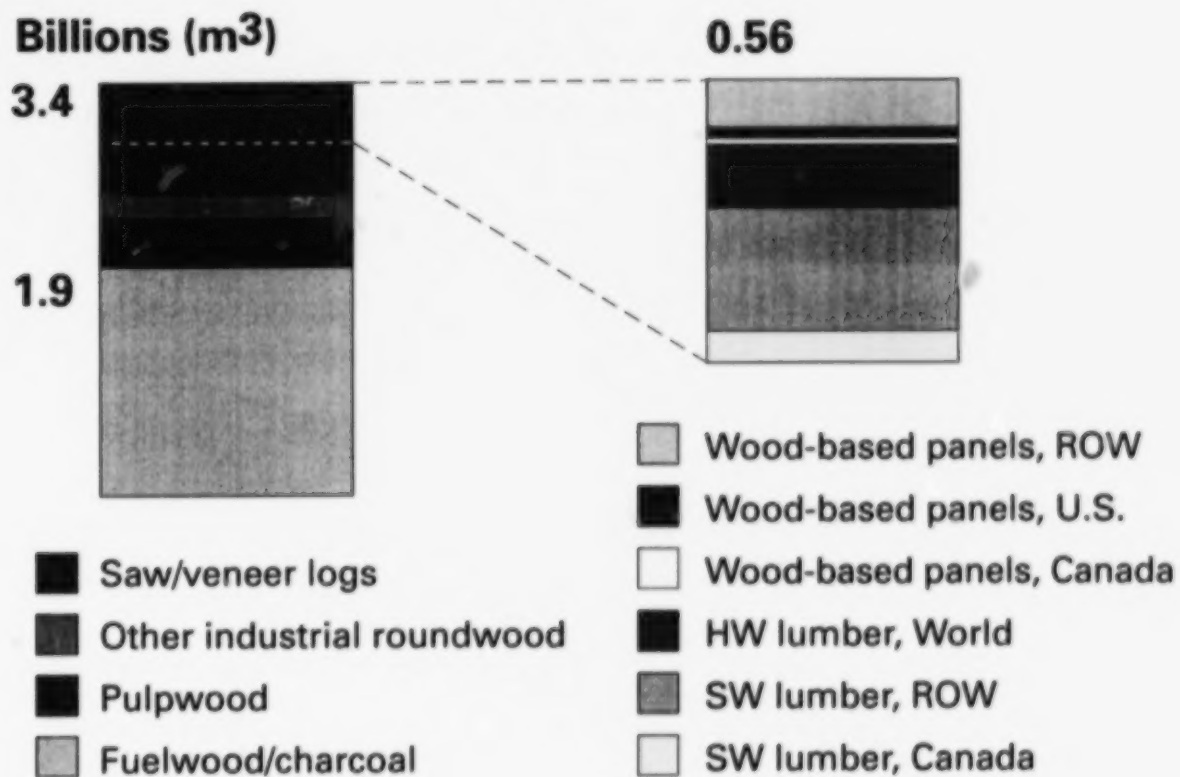
Annual World Consumption of Wood

**Industrial
Roundwood
1.7 billion m³**

**Fuelwood
1.8 billion m³**

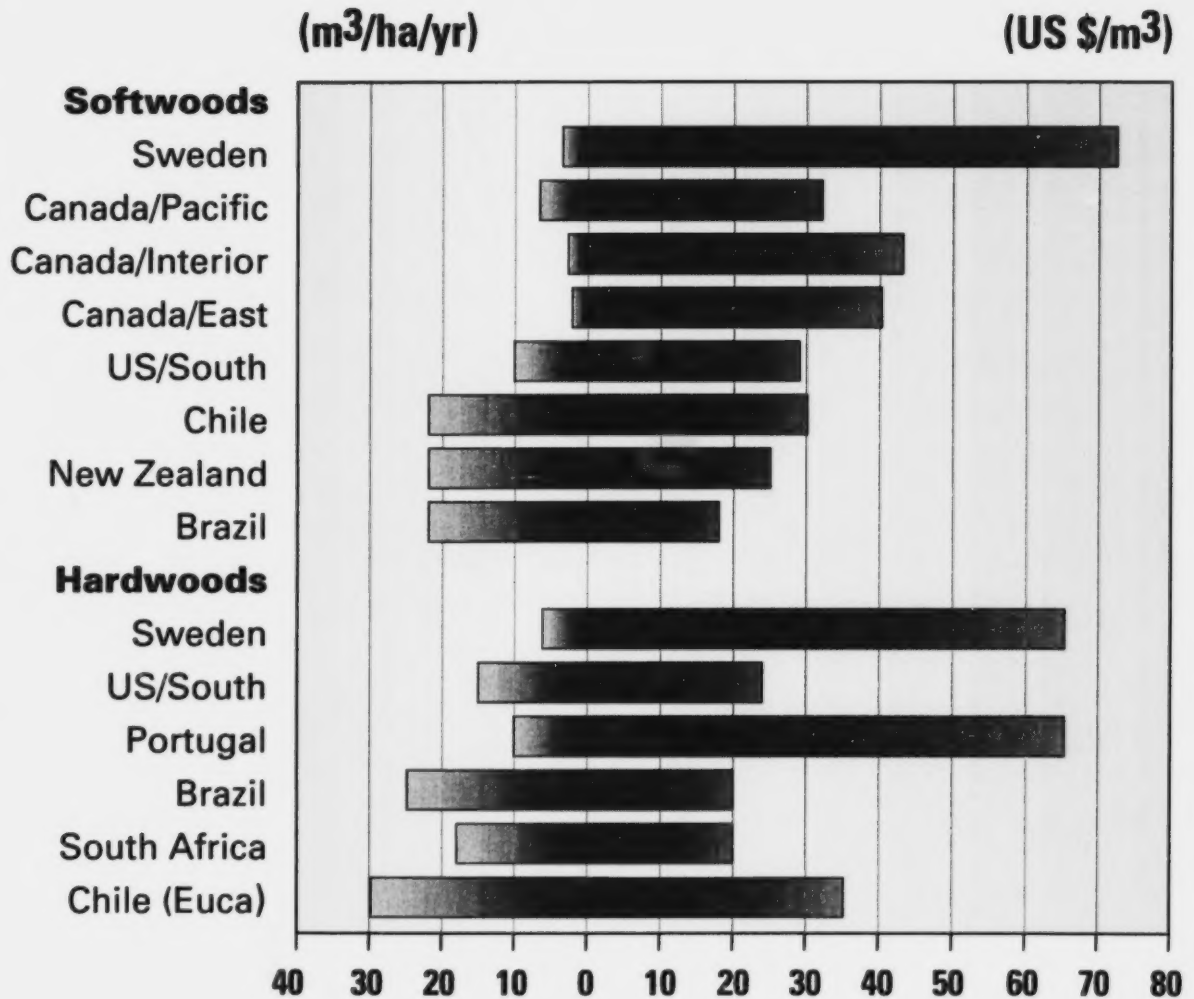


Global Production of Fibre



Source: FAO

Growth and Mill Delivered Cost of Pulpwood – 1/91



OVERHEAD 11

When we look at productivity rates ($\text{m}^3/\text{ha}/\text{yr}$) and the cost of mill-delivered wood, it is hard to imagine that Sweden and Canada can compete with countries like Brazil, New Zealand, and Chile.

Global Competitiveness is possible through a fine balance of biology, technology, and political stability.

Biogeoclimatic reality is something we cannot escape, it is a bit like our genetic code. The genetic potential of our tree species, soil/site quality, and climate actually provides us with an excellent quality resource; what we lack in quantity we make up in quality.

Technology implies a trained work force, the ability to use the most current, efficient, and environmentally friendly processes, and lastly, an efficient infrastructure.

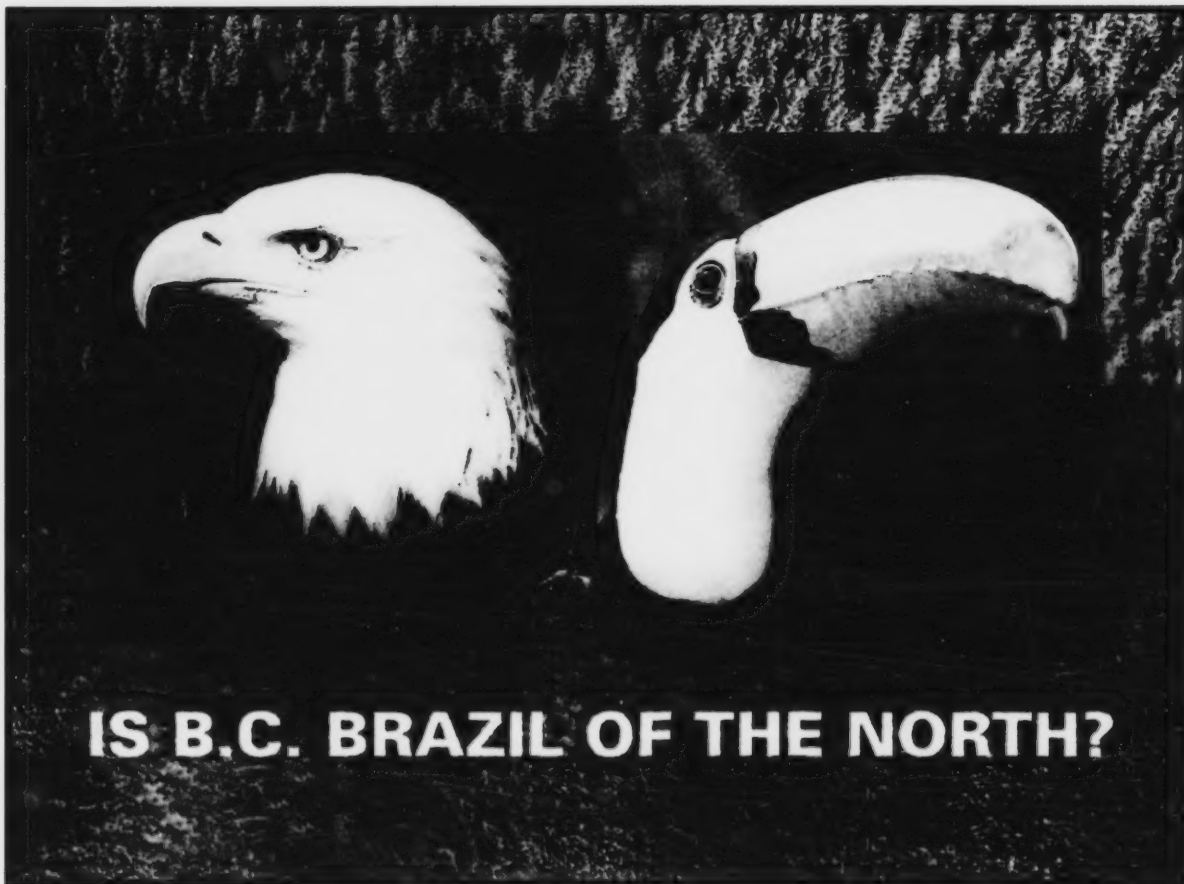
Political stability is self evident. Investors need confidence in recouping their capital investment over a long period of time.

No other nation, country, state, or province is as dependent on the forest products industry as British Columbia; out of every \$1 revenue, 65% of our trade balance comes from forestry... in the next closest countries (like Sweden and New Zealand) this figure is at 35% or less.

For a leading economy to remain in the lead, it needs the following:

1. Avoid complacency
2. Innovate, Innovate, Innovate (hence the need for R&D).

The East Asian Miracle in the last 20 years was based on: **hard work, openness and competitiveness, a passion to learn, a willingness to change, and an optimistic attitude.**



OVERHEAD 12

Are we Brazil of the North?... of course, we are not. The environmentalists coined this very catchy phrase, in criticizing BC logging practices of a decade or so ago.

If we looked at climate and natural riches alone, Brazil would be one of the richest countries in the world. As we know from the nightly news, it is not!

Brazil is only 15% smaller than Canada (8.5 compared to 10 million km²), but it has at least six times the population (150 compared with 26.3 million), GDP/capita in USA \$1 980 vs \$21 813.

Brazil harvested 90 million m³ of wood last year for industrial purposes, and harvested another 190 million m³ of wood for heating, cooking and for making charcoal.



This thinning operation is at
age 23. About 3 years later
this stand will be clearcut
and replanted.



OVERHEAD 13

Hybrid Caribbean pines are grown south of 23 degree latitude. Any closer to the equator is too hot for pine. They plant 2500 stems per hectare, prune every tree at age four, and they return to thin every three years. By the time of harvest, at age 26, they end up with 500 stems/ha. In 26 years they will have entered the stand eight times. The pine plantation at Duratex was 40 000 ha (about 100 Stanley Parks). All forest roads were in place to the sawmill and hardboard plant; the longest hauling distance was 15 km.

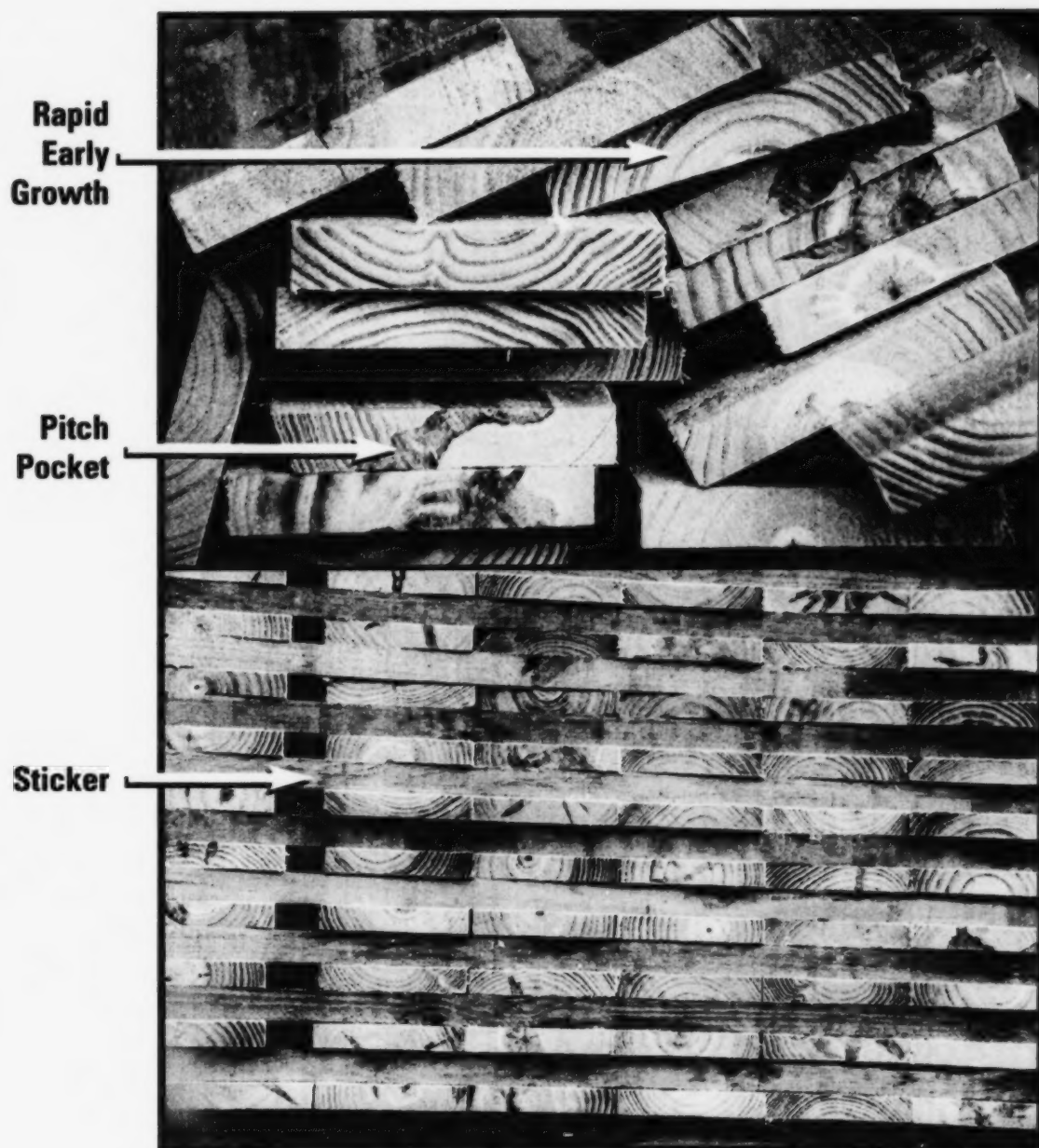
Even a seemingly ideal "textbook" operation is not so. In case of both pine and eucalyptus plantations, other crops are more lucrative to grow (e.g., sugar cane, citrus fruits, coffee).



26-year-old Caribbean
pine hybrid.

OVERHEAD 14

Caribbean pine logs, after debarking. Note heavy pitch oozing from the log ends. Butt logs are about 40 cm (16 in.) in diameter, and 26 years of age. These logs contain 100% sapwood, with >200% moisture content (this means that for every unit weight of bone-dry wood there are two unit weights of water).



OVERHEAD 15

1.5 inch thick boards of Caribbean pine, after kiln drying.

Please note:

- about 35% of the boards have pitch-soaked wood
- extremely rapid growth rate next to pith, first 3–4 years
- varying amounts of dark latewood
- distinct annual rings
- 1.5 in. thick stickers to facilitate efficient airflow during lumber drying.



Wood Quality... Impact on Product Yields, Grades and Value

BRAZIL AND NEW ZEALAND

16.0

OVERHEAD 16

Eucalyptus grandis hybrid clonal plantation, where different clones are being evaluated under identical site conditions.

Please note: excellent self-pruning, small crowns (a lot of sky is evident in the overhead shot), at age six these trees were the same size as the average lodgepole pine tree harvested in BC in 1994.....

19 cm DBH and 26 m tall, but 125 years of age.



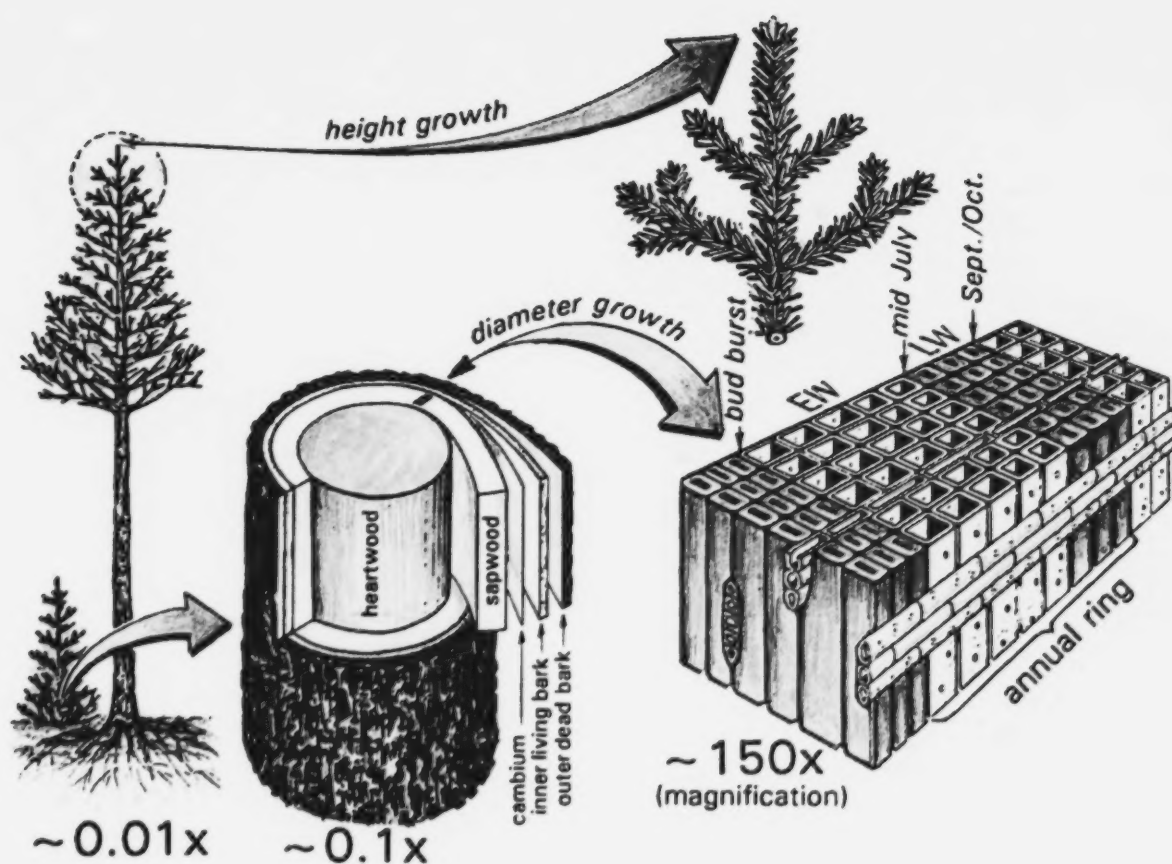
**By the year 2040
New Zealand could harvest
85 million m³ of wood annually,
all plantation grown.**

OVERHEAD 17

We can take a lead from the New Zealanders in terms of promoting our commercial tree species. They have published a number of books that describe the properties and uses of NZ radiata pine, covering the whole spectrum from seedling to the machining properties of the wood. They have already introduced clear radiata pine wood into the USA Pacific Northwest for window manufacturing.

Most serious problems with radiata pine wood include coarse grain (wide rings), prominent resin canals, and **excessive spiral grain** in the first 10 years of growth.

Advantages include good workability, and excellent permeability (in pressure treating with preservatives, the wood gets treated throughout the piece in minutes, even with thick pieces).



OVERHEAD 19

Describe different tissue types and their respective roles in a living tree. Spend some time on the important transport corridors in the living bark and sapwood. Arrive at the important sapwood/heartwood differences in terms of permeability, moisture content, extractives content, and natural durability of some of our woods.

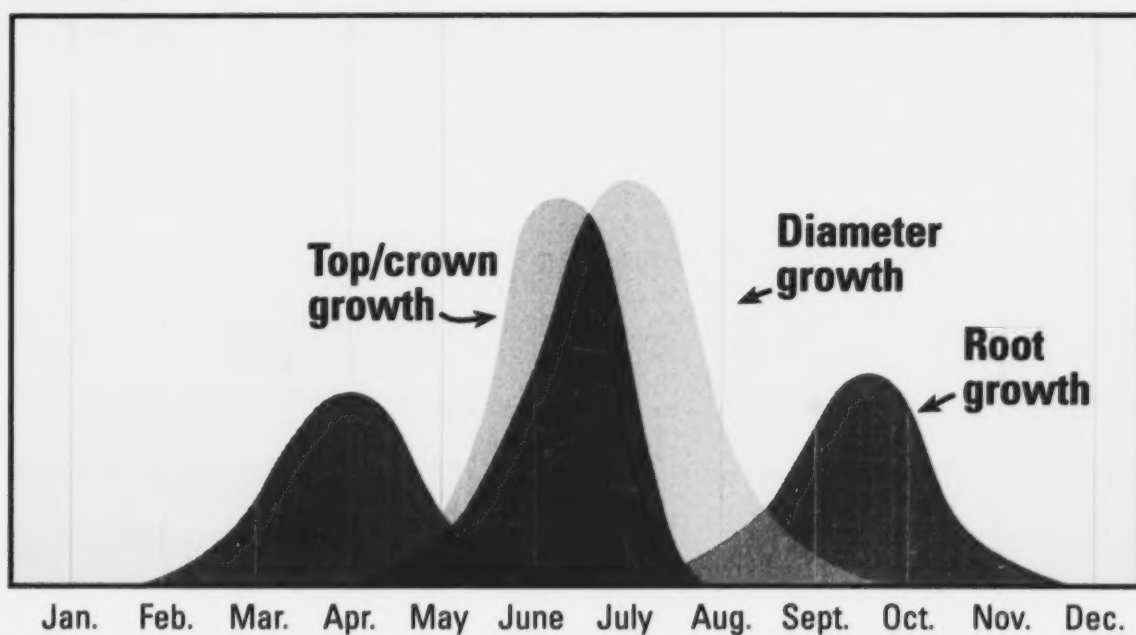
Question and “tease” about that invisible barrier that separates the dry heartwood (50% M.C.) from the wet sapwood (150% M.C.). This wood quality attribute is extremely important in pressure treating telephone poles (western redcedar poles must have at least 1.5 in. sapwood on the outside), in lumber drying (sapwood dries faster and easier), in chemical pulping (in terms of liquor penetration).

In terms of silviculture, explain how ringing the tree (cutting off the inner bark) interferes with photosynthate translocation, and fine root-hairs can not grow (for lack of food) and the “tree starves to death”. This knowledge is being utilized to control unwanted vegetation in newly established stands where herbicides can not be used.

For example, what is one to do if red alder becomes an aggressive colonizer in a newly established Douglas-fir plantation? Cutting the alder trees simply does not work because 20–25 new suckers shoot up from the stump, making a bad situation worse. Ringing the trees does work, provided there is no inner bark tissue left behind in the ringed portion (the author has observed that trees have a tremendous capacity to repair themselves).

Phenology of Tree Growth

**Relative
activity**

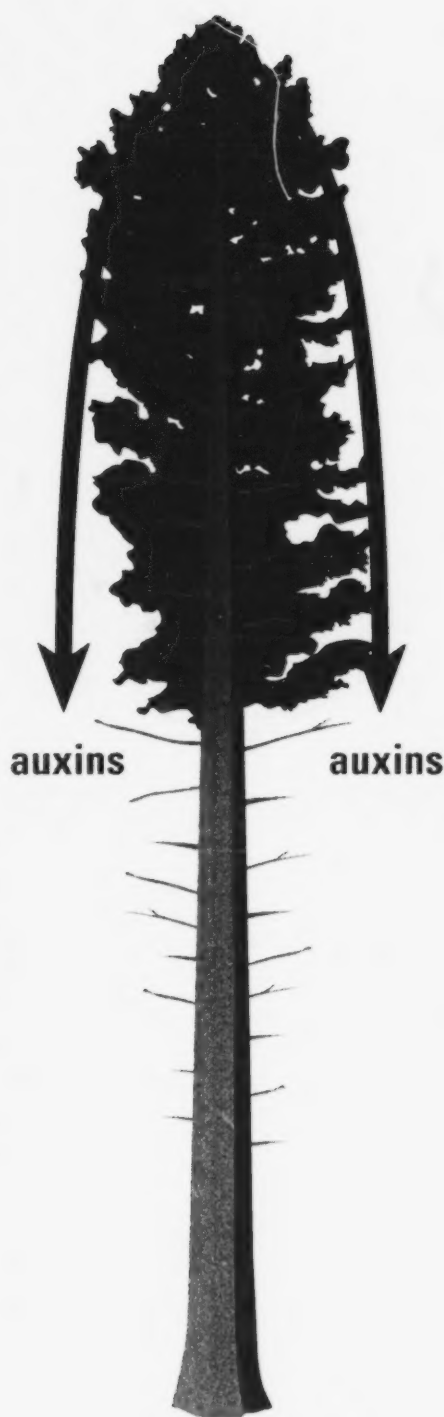


OVERHEAD 20

Describe the phenology of root, crown and stem growth. Contrast determinate and indeterminate tree species in terms of height growth, earlywood/latewood formation.

This discussion is extremely important in the context of the window of opportunity for latewood formation (on average, from mid-July to the end of September) and the lack of moisture in some parts of the province. Refer to the low-density Douglas-fir in the Rocky Mountain Trench and the high-density lodgepole pine in the ICH (more research is needed to prove the hypothesis).

Corollary discussion should include the amount of energy that goes into producing fine root-hairs, and the preferred times of transplanting trees with high success ratio. High rate of physiological activity in June and July makes trees vulnerable and doing pruning at this time could result in excessive mechanical injury.



-
- Terminal shoot and vigorous last formed portions of the crown foliage produce growth regulating hormones (auxins) and photosynthate.
 - Lateral and downward translocation of auxins to reach lower stem.
 - In spring radial growth begins first at the top of the tree and proceeds gradually downward = more EW and wider rings in upper crown region near pith.
 - Less EW and smaller rings at the base where rings are far from pith.
 - Transition to LW occurs first near the base, farthest from the source of auxin supply and proceeds upward.
 - The destiny (and density) of an individual fibre is thus determined by its relative position; its distance from the active live crown region and the time of its formation (season).
-

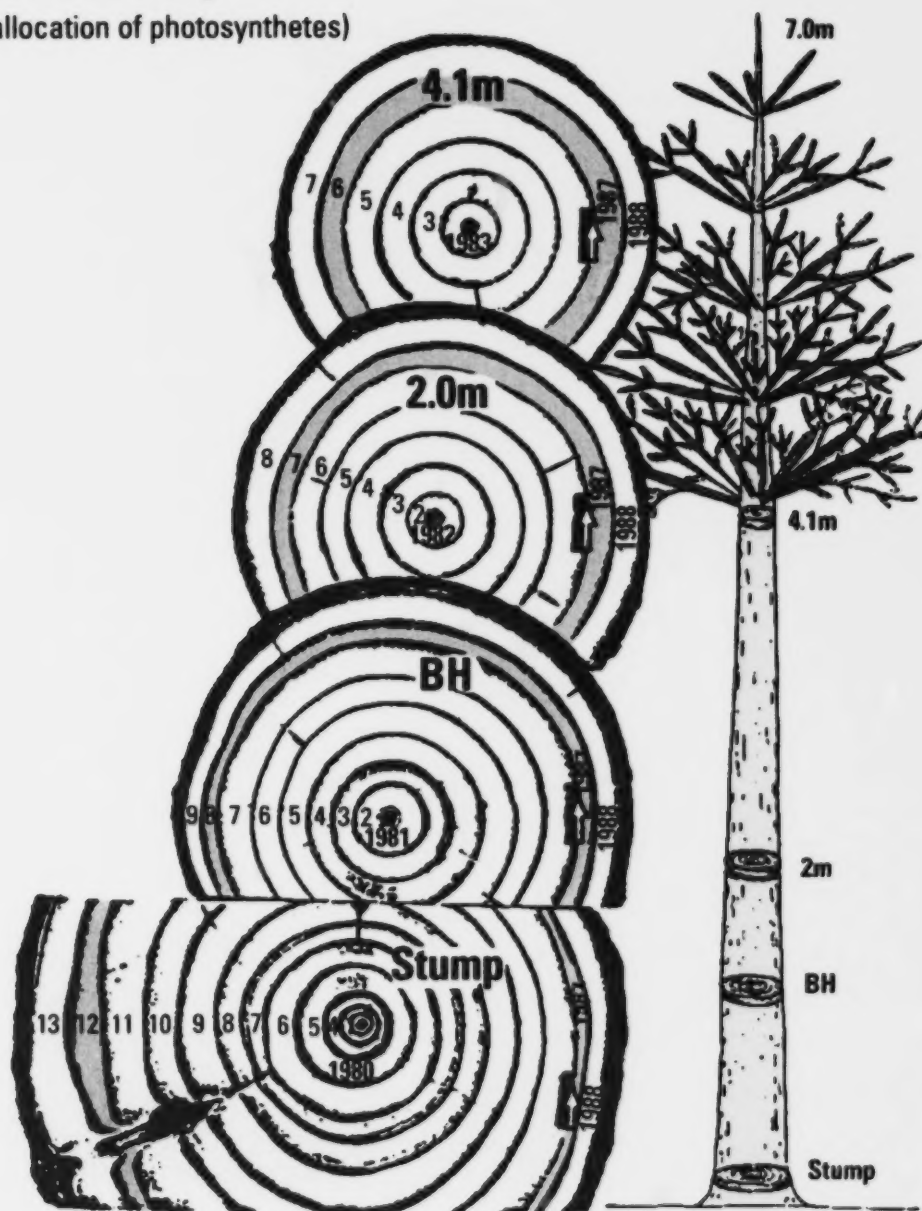
OVERHEAD 21

In addition to the bullets on this overhead, contrast a fully open-grown tree with a “dog-hair-stand” type of stem with little taper.

To force the right train of thought, ask what is the difference between a 20 year old thinned stem (lying on the ground), and the last 20 years of growth at the top of a 60–80 year old Douglas-fir or lodgepole pine. The discussion should include branch size, height growth, diameter growth, and compression wood formation. The major factor of mortality should be brought into the discussion. Therefore, the top of an older tree will have developed in a more open environment.

Allometry

(allocation of photosynthetes)

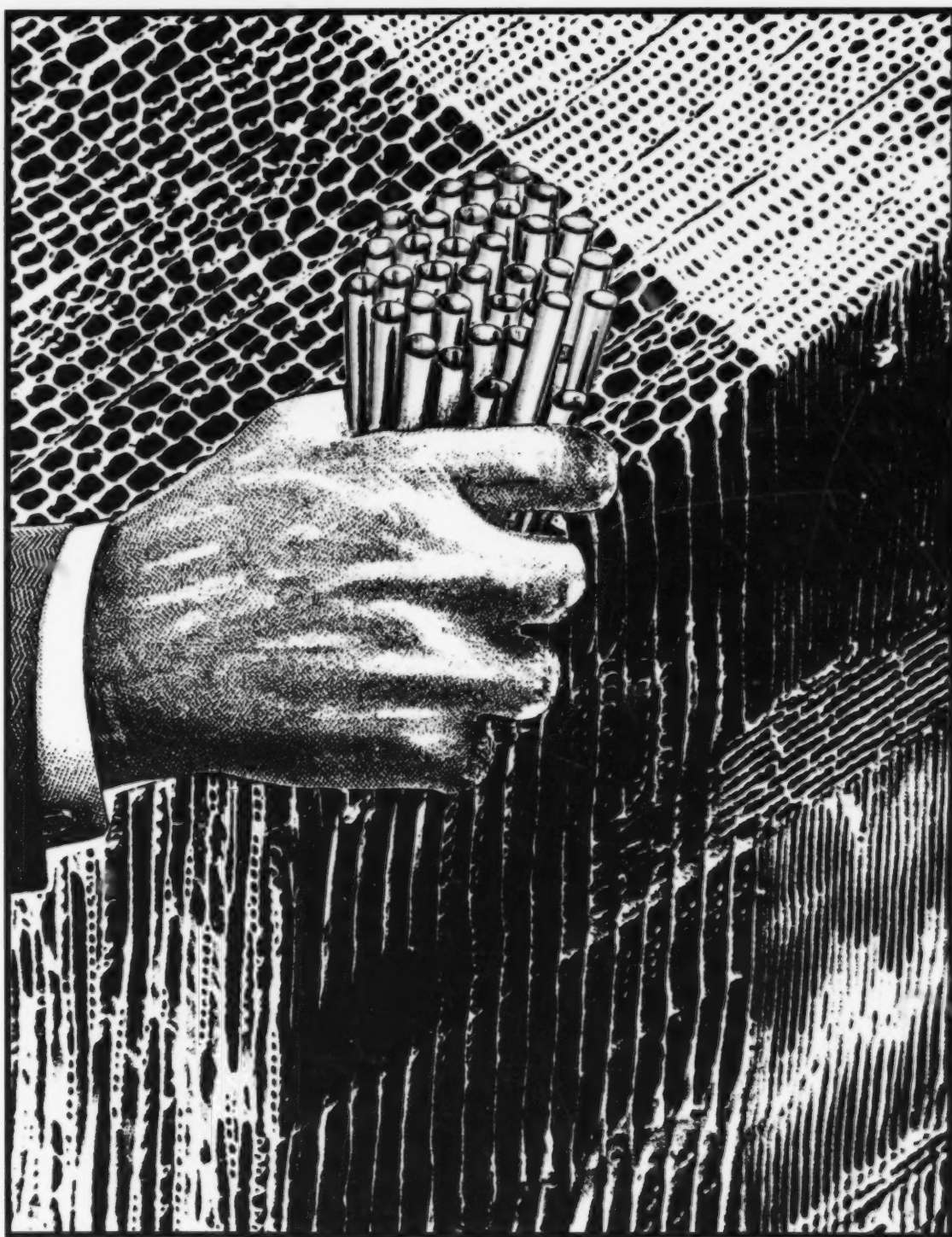


OVERHEAD 22

Describe **allometry**, or “building block” allocation in a tree. Use this overhead to illustrate the point; the same growth layer, immediately after pruning, gets short changed at the base of the stem. In big and old trees, growing with moisture stress, the trees can have “locally absent rings” and “missing rings” at breast height.

Simplified allometry (energy allocation in order of priority):

- No. 1 fine root-hair production (can be up to 40% of the tree's energy)
- No. 2 crown development, including seed production
- No. 3 the “leftover” for stemwood production.



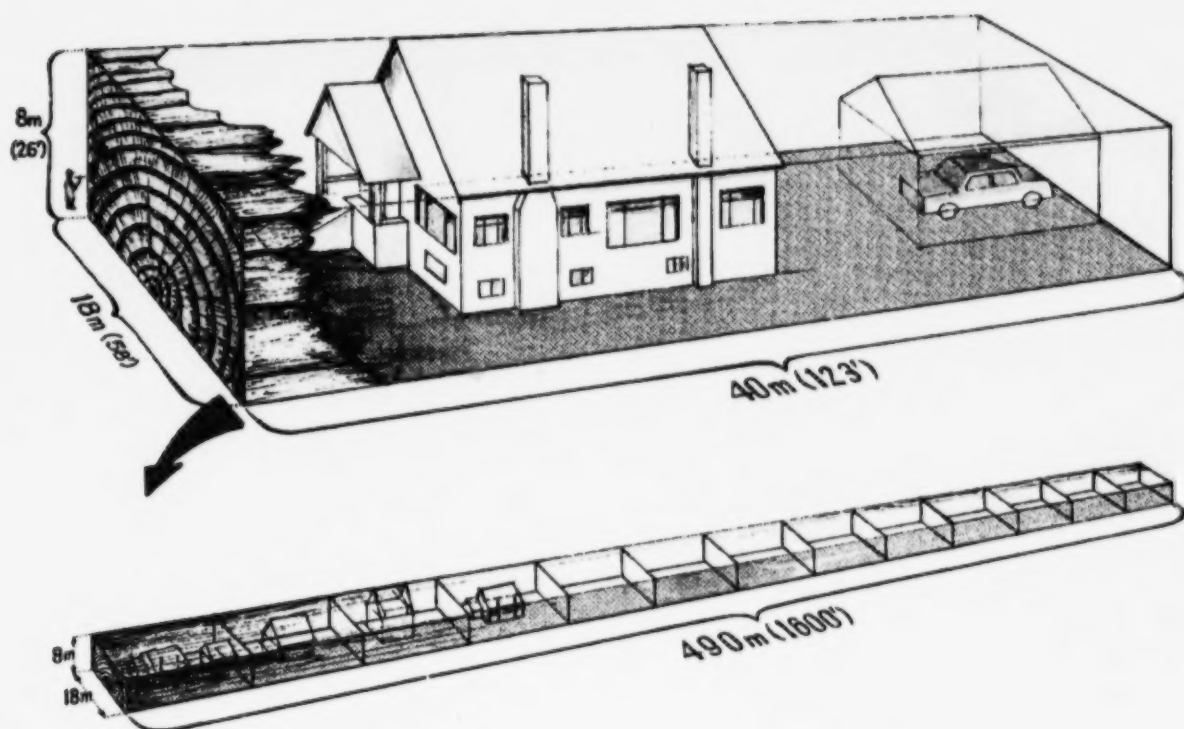
OVERHEAD 23

Explain the need for magnification when examining wood structure. For example, even with perfect vision, the human eye cannot separate two point objects that are closer together than 0.1 mm; this is our limit of resolution. It just so happens that about 3–4 softwood fibres fit into this 0.1 mm space. For this reason at least a 10× handlens, or preferably a microscope is used in the study of wood structure.

A handful of hollow milkshake straws would give a good approximation (about 94% correct) of wood structure at 200 times magnification. Of course, we would have to introduce plastic coffee stirrers to represent the horizontally aligned rays (now we have a 99.9% true representation of softwood structure).

Remind the class that at this magnification, a complete fibre length would be about 70 cm long, or 100 times of its diameter.

Explain the anisotropic nature of wood because of its structural makeup.

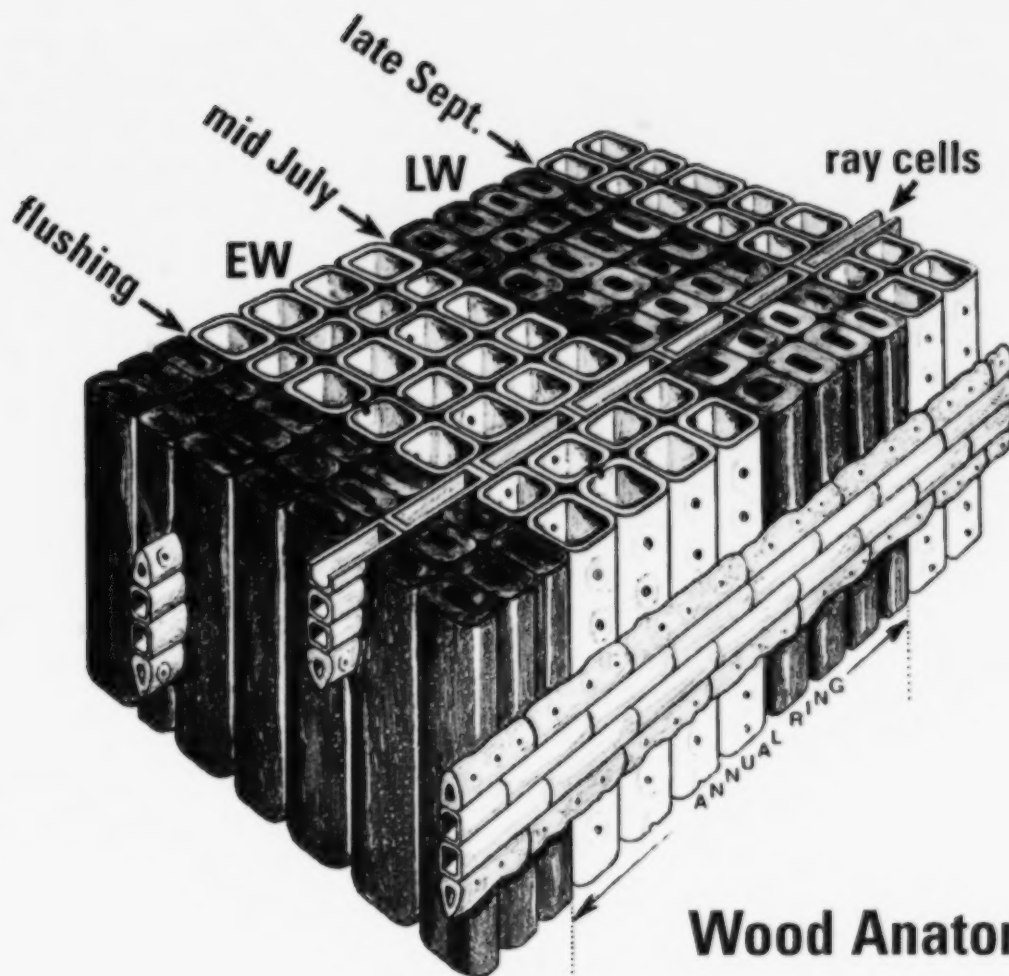


OVERHEAD 24

It would be easy to gloss over the concept of 200× magnification. But we will not. Consider a piece of eight foot long 2×4 , magnified 200 times: it would be 1600 feet long (490 m), it would be 2.5 stories high (8 m), and 58 feet (18 m) wide.....now fill up 94% of this volume with 70 cm long milkshake straws, and the leftover 6% volume with coffee stirrers. Now you have a good appreciation of wood structure.

For lumber drying, keep in mind that we are trying to remove water from a fibre located in the middle of this 2×4 ; 4 m up from the ground, and 4 m from the top, 9 m in from the sides, and 245 m in from the ends of the board.

The 8' long 2×4 will contain on average about 2.5 billion wood fibres (for an average lifespan the human heart beats 2 billion times).



Wood Anatomy

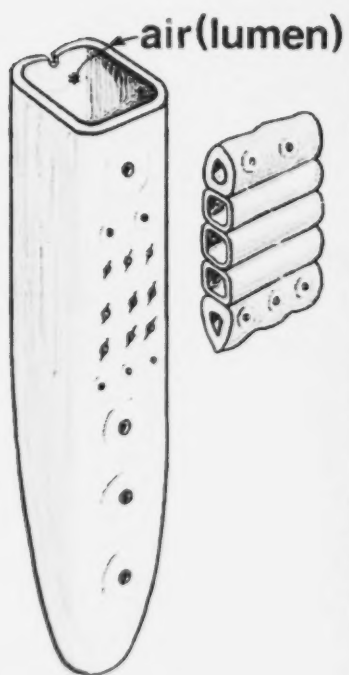
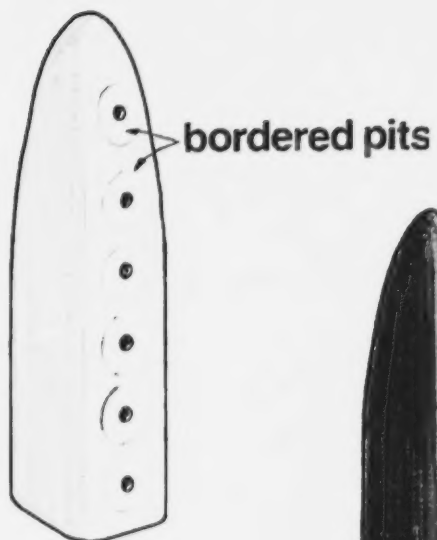
OVERHEAD 25

Review annual ring formation. Do a class survey and ask for estimates of **active tree growth**; how many months, out of the 12 month calendar year, do trees actually grow in Butchart Gardens?

Most people tend to confuse photosynthesis with tree growth. In fact, photosynthesis happens every day when temperature is above freezing. For example, during the dormant season (October to March) Sitka spruce seedlings doubled in bone-dry weight in Ireland; although there was cell division photosynthates accumulated in the seedlings' tissues.

Talk about early wood/late wood (EW/LW) fibre morphology.

Earlywood

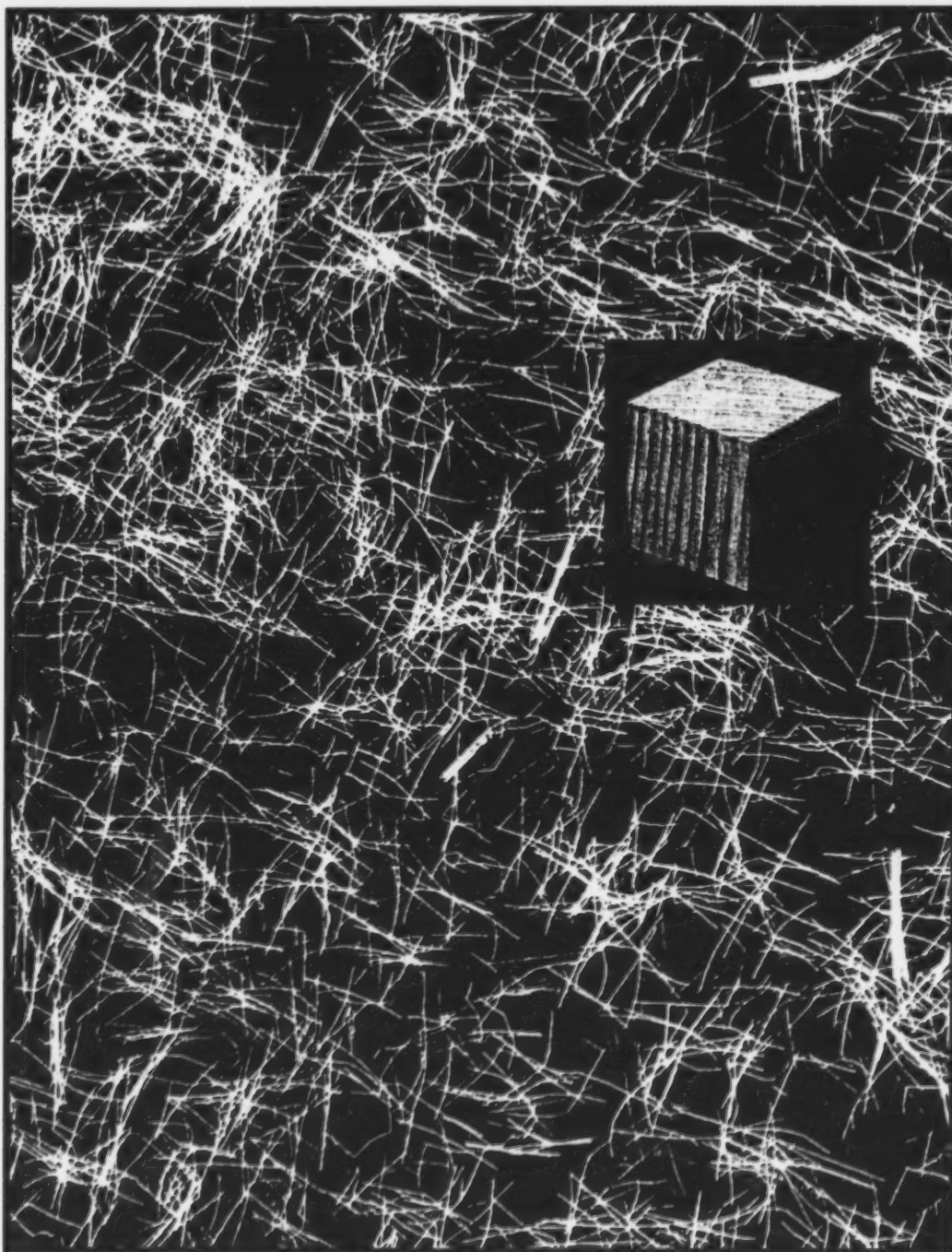


Latewood

OVERHEAD 26

Introduce fibre models at 4 000× magnification. Drive home the edge-grain/flat-grain differences at the microscopic level, and conclude with an opinion survey of which face dries faster? Which face performs better when painted? Show examples if possible.

Do the fingernail test for EW/LW on the flat-grain board (more on this later on).

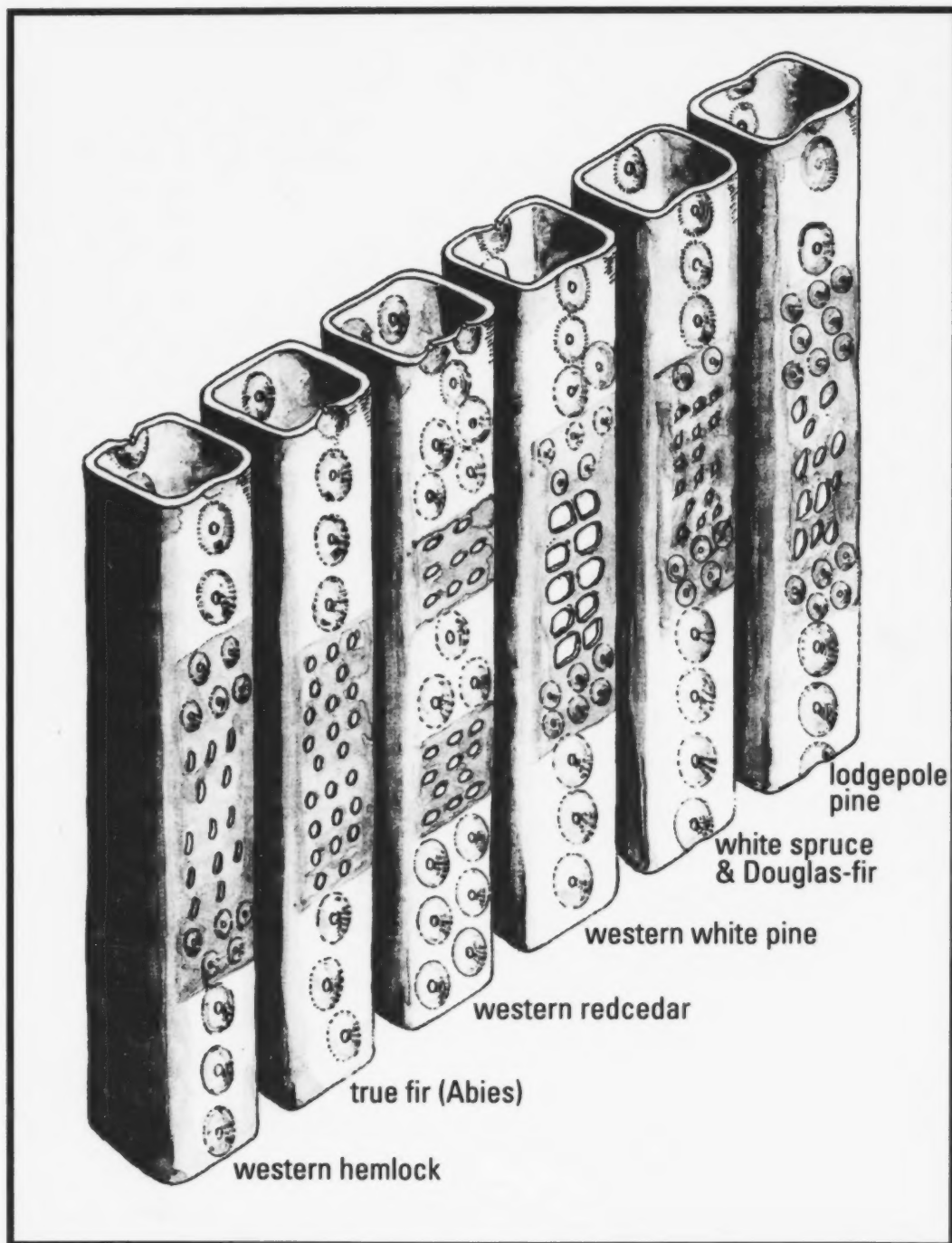


OVERHEAD 27

Explain the basic concept of chemical pulping; dissolves lignin bond, about 45% yield (lignin, hemicellulose, and extractives are "lost down the drain"). Contrast this with mechanical pulping where yields are about 95%, because the fibre-to-fibre bonding is broken by mechanical action. Therefore, in mechanical pulping the losses are minimal (usually in the form of water solubles and fines).

Tie these concepts back to the 2.5 cm wood cubes, by showing how much heavy shopping bag Kraft pulp can be made from just one cube (45% of its weight, about one half of an 8.5 × 11 in. sheet of paper). Demonstrate with double-ply toilet tissue the mechanical pulp yield from the same cube (about 20–24 squares, or close to 2 m long piece).

- a 2.5 cm softwood cube contains 5 000 000 wood fibres, each about 3.5 mm long.
- if these 5 million wood fibres were laid end-to-end, the total distance spanned would be 17.5 km.



OVERHEAD 28

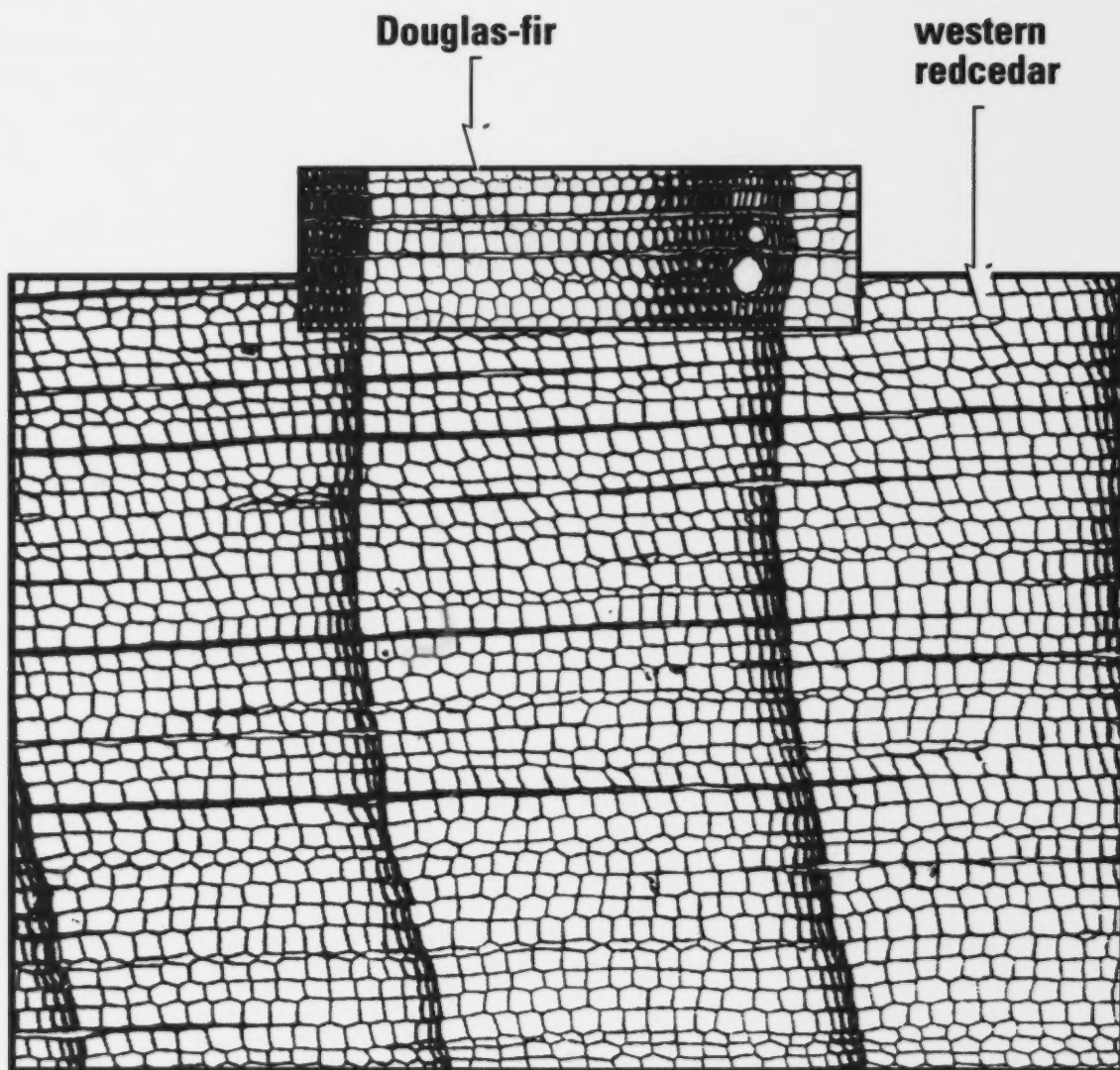
The technique of wood identification is not unlike identifying different makes of cars; that is, by noting their size, shape, proportions and ornaments. With experience it is possible to pinpoint not only the make but the particular year of manufacture.

The ultimate ideal in wood identification is the complete familiarity not only with the diagnostic structures and features, but also with the degree of natural variation to be found in wood from different trees of the same species.

Identification of wood fibres in paper is a challenge even to the seasoned professional. The challenges arise because the anatomical relationships of the cells to one another no longer exist.

The most important thing to remember about species identification of softwood paper fibres is that diagnostic features can be found only on earlywood fibres. Specifically, in the ray-contact areas (crossfields), where the size, shape and the number of ray crossfield pits can be seen. Remember that these features are found exclusively on the radial face (edge-grain) of the cell wall.

Bullets: radial/tangential plane, bordered pit function in sap/heart (show the model at 10 000 $\times$), ray-crossfield pits, etc.

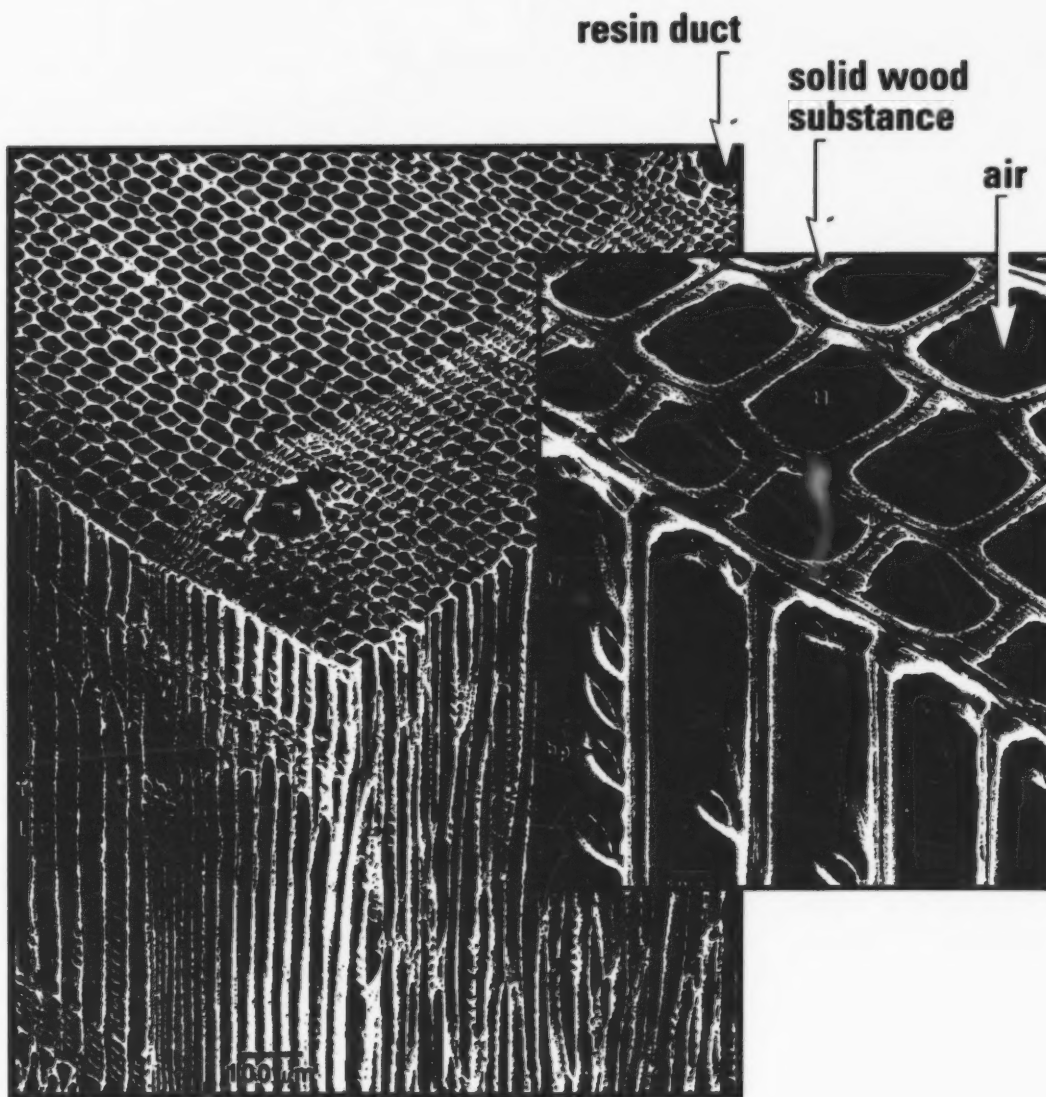


OVERHEAD 29

The white you see in this cross-section is air. Solid wood substance resides in the black filigree. Heavy horizontal lines are rays, vertical black bands are latewood fibres in this low-density old-growth western redcedar.

Note distance scale: the 1 mm long black horizontal bar, and the two annual rings bracketed (they are less than 0.5 mm wide). This rate of growth works out to be about 50 rings/inch!

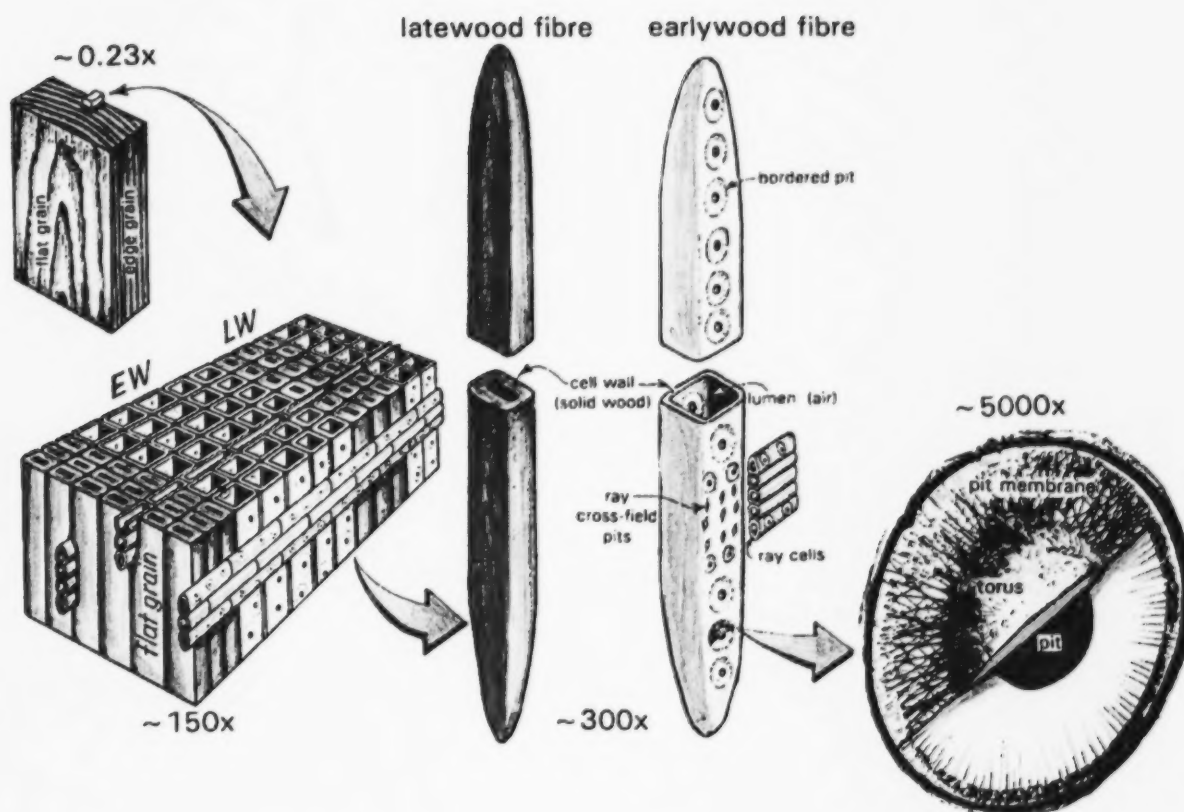
Equally interesting is a small insert in the top of the picture (perhaps this can be revealed at a later time in the discussion, so the viewer is not sidetracked), showing one complete Douglas-fir ring. Draw attention to the similarities and differences (almost identical cell diameters, fibre wall thicknesses; except there is a pair of resin canals, and there is a lot more latewood, with much thicker cell walls).



OVERHEAD 30

Describe and summarize the location of solid wood substance, air, middle lamella (the cementing medium that has to be dissolved through pulping). At this stage , demonstrate with wood cube models at various magnifications (150, 200, 1200, 1300, 4000, and 10 000 times).

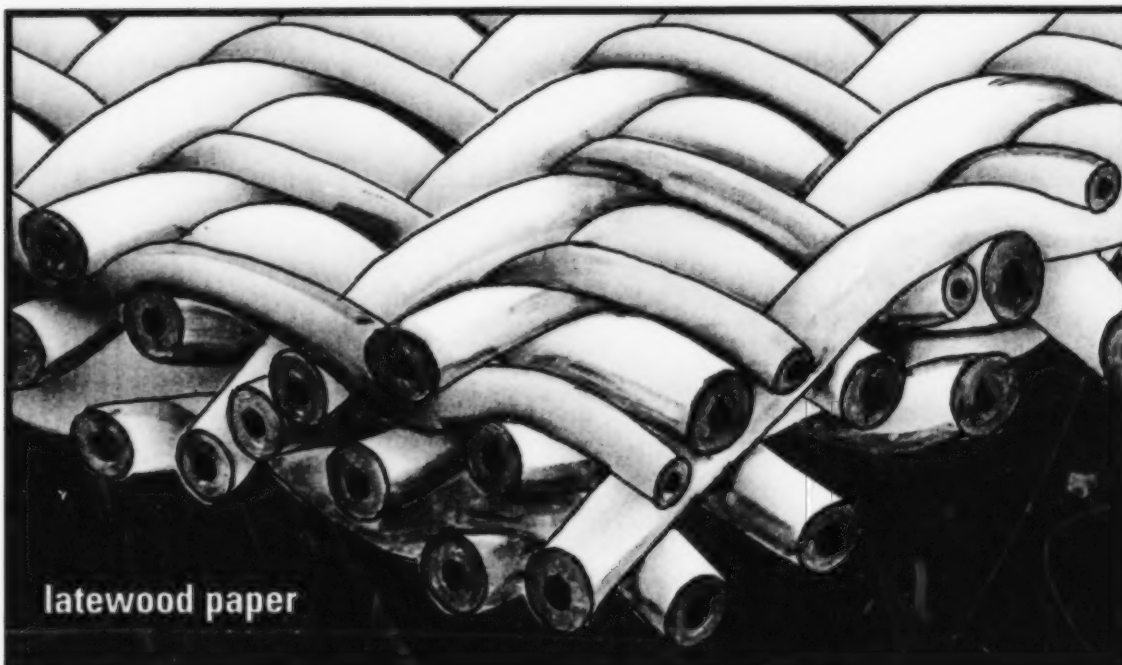
Describe some of the tree species with and without resin canals, and the concept on traumatic resin canals in non-resinous woods.



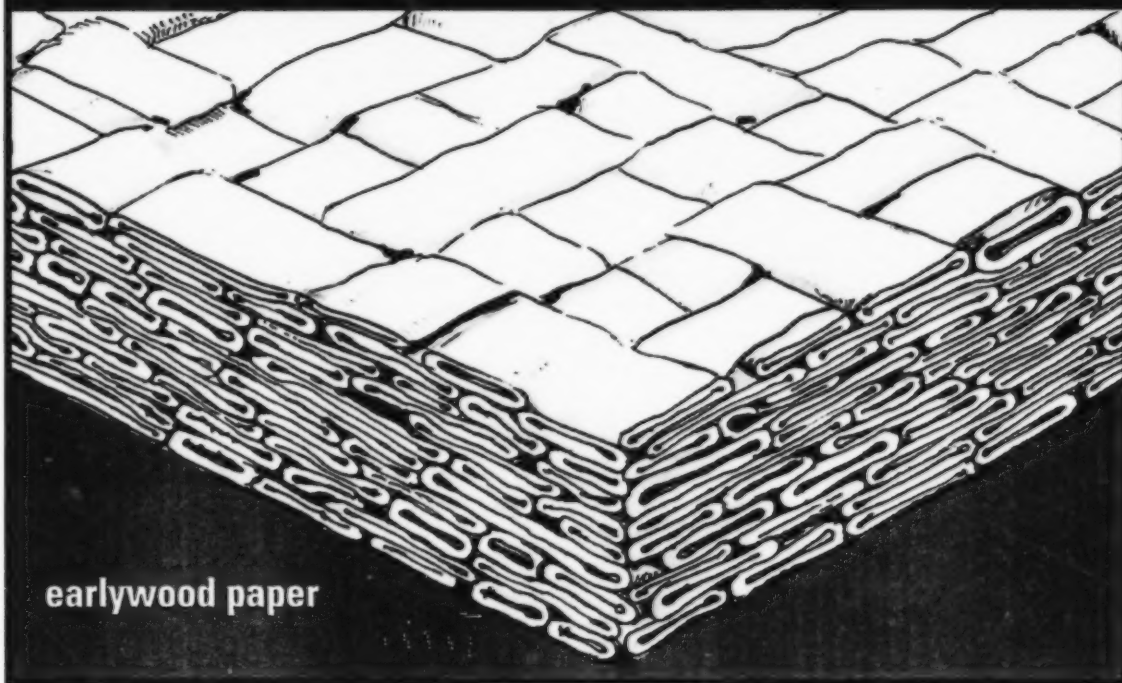
OVERHEAD 31

This is the concluding overview of wood structure, both in terms of organization and function. For the solid wood products sector anisotropy is important in terms of appearance, workability and performance.

The usefulness of progressively higher magnification, revealing structural elements was demonstrated through the overheads and various props.



latewood paper



earlywood paper

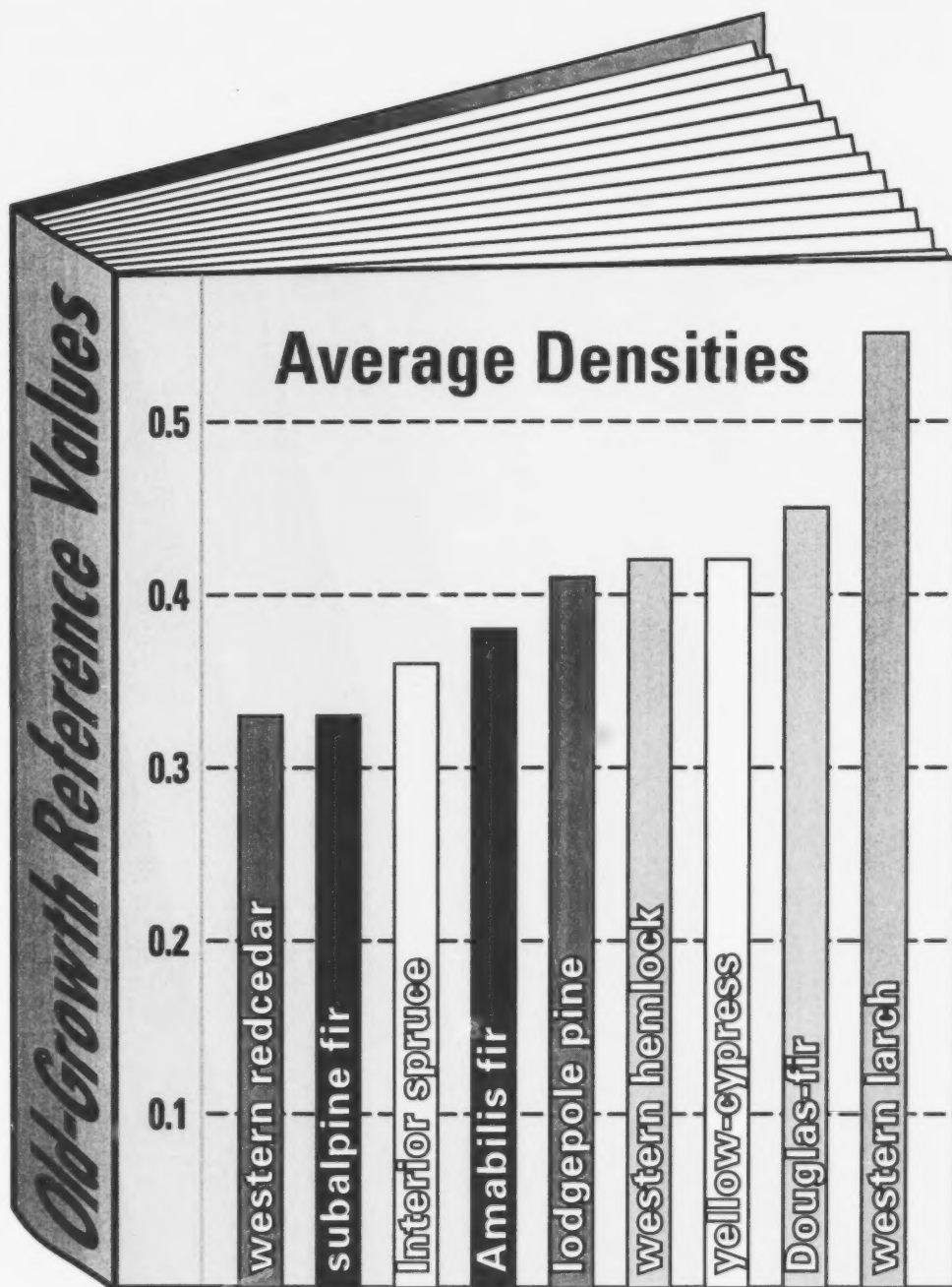
OVERHEAD 32

Fibre morphology principles are demonstrated here to the paper maker: earlywood fibres collapse to a ribbon-like form, while thick-walled latewood fibres remain rod-like (from the surface of fine printing papers they tend to stick out like the ribs of a starving animal).

As in solid wood products manufacturing, "uniformity" of the fibre furnish is the key to an efficient pulping and papermaking sector. At one time "fibre length" used to be one of the most important quality descriptor, then "weight per unit length" (or fibre coarseness), and today it is "fibre collapsibility".

Sketch out the performance requirements for Kraft paper shopping bags, fine writing and printing papers, and tissue products, and the linkages between wood/fibre quality. Key words are burst, tear, opacity, printability, and absorbance.

Conclude with the "sawlog mentality" in BC, how sawmill waste provides the furnish for pulp and paper (and not old-growth logs from the Clayoquot). Currently, about 90% of the chips come from sawmill waste (slabs, planer shavings, and sawdust), and the other 10% comes from the relatively low-quality pulp logs.



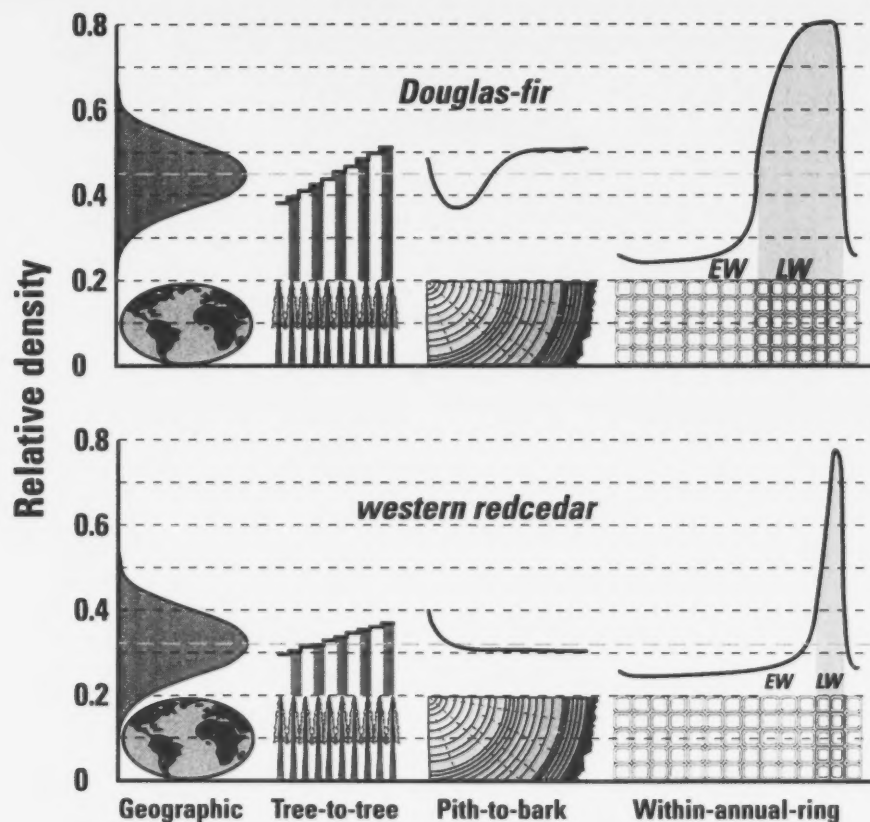
OVERHEAD 33

Relative density of wood can be viewed from a variety of different perspectives. This overhead shows the “global” average **old-growth** wood density values of some of the important BC softwoods. These are reference values, which were established through density surveys not only in Canada, but in the USA as well.

Provide clarification about terminology: in the metric system the preferred term is **relative density**, a unitless term, NOT TO BE ABBREVIATED. Therefore, the term specific gravity is no longer in vogue. **Basic relative density** means oven-dry weight over green volume.

The reference values shown here come from a Forintek publication, *Conversion Factors for the Forest Products Industry in Western Canada*.

Global to Microscopic View of Density Distribution in BC Tree Species



OVERHEAD 34

The best way to discuss this overhead is to cover up 3/4 of it (showing the two globes) and talk about the major differences between Douglas-fir and western redcedar. These two species represent the highest and lowest density softwoods, **0.45** and **0.33**, respectively. **These are old-growth reference values!** One can think of these values as "global" (macroscopic) in nature. The other extreme viewpoint is at the microscopic level, where solid-wood substance basic relative density is 1.1, and lumen (air) is 0. These two limits leave us three intermediate points to discuss:

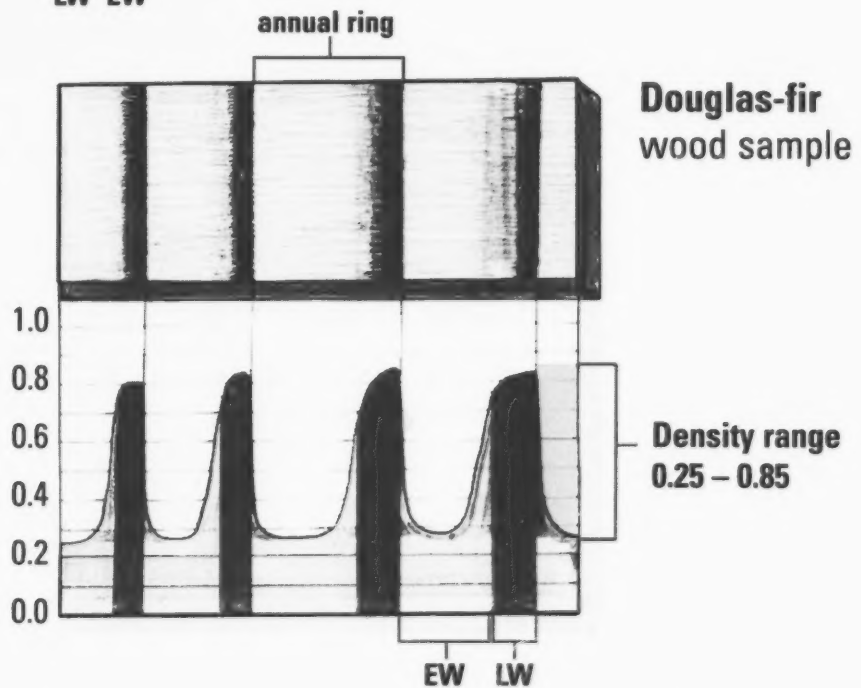
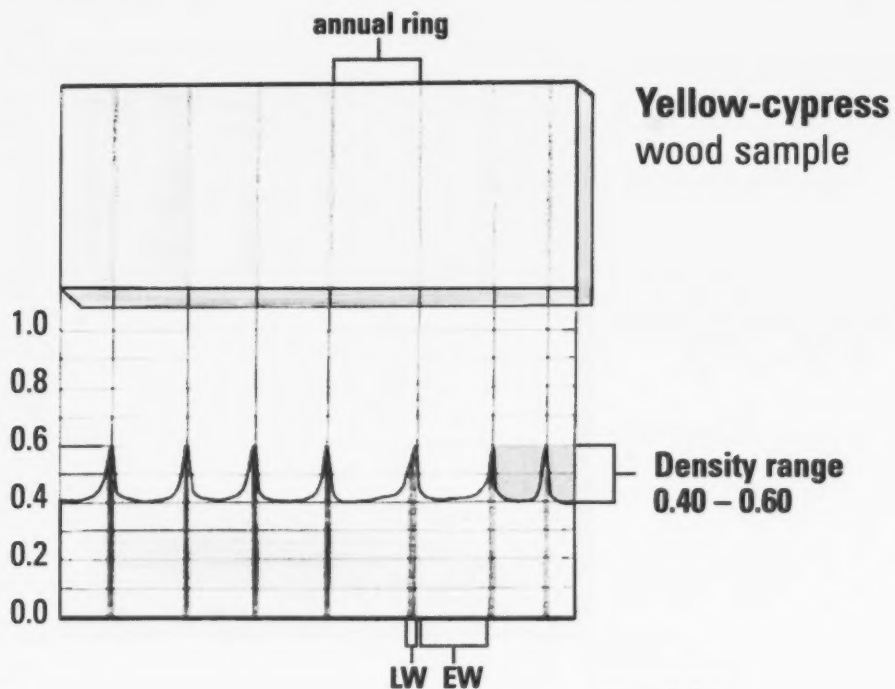
1. **tree-to-tree**
2. **pith-to-bark**
3. **within annual ring density distributions.**

In terms of tree-to-tree density differences (within any one species) the normal coefficient of variation (not to be confused with coeff. of variance!) is 10%. Therefore, in western redcedar and Douglas-fir the normal range in relative density is 0.26–0.40 and 0.36–0.54, respectively. These limits would include 95% of a normally distributed population.

For pith-to-bark density distribution refer to Special Publication SP-34, page 12–14. These two examples in overhead 33 simply represent the most- and least-dense woods.

Within-annual-ring density variation is described in great detail in SP-34. In this overhead the main point to be made is that earlywood and latewood densities are very similar in these vastly different tree species. Ultimately, overall density differences are attributed to differences in latewood content (as was demonstrated in overhead 28).

Wood Density Variation within Growth Rings



OVERHEAD 35

Wood density variation within growth rings are to be described in terms of working properties (machinability) and appearance. This is detailed in SP-34 on pages 8 –11.

Show some wood samples with edge- and flat-grain. Draw attention to the lack of grain (not much visual contrast between EW-LW) in yellow-cypress, and to the very “contrasty” Douglas-fir. Invite students to dent the wood with their fingernails. Of course, Douglas-fir latewood will not dent, but earlywood will. In addition, show that yellow-cedar earlywood is tougher than in Douglas-fir.

Juvenile Wood

(wood that is formed in the live crown)



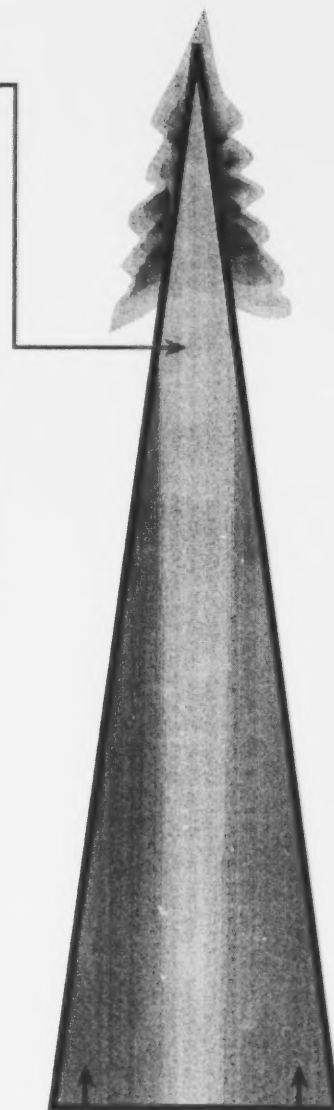
8

20

35

85

(years)



mature
wood

OVERHEAD 36

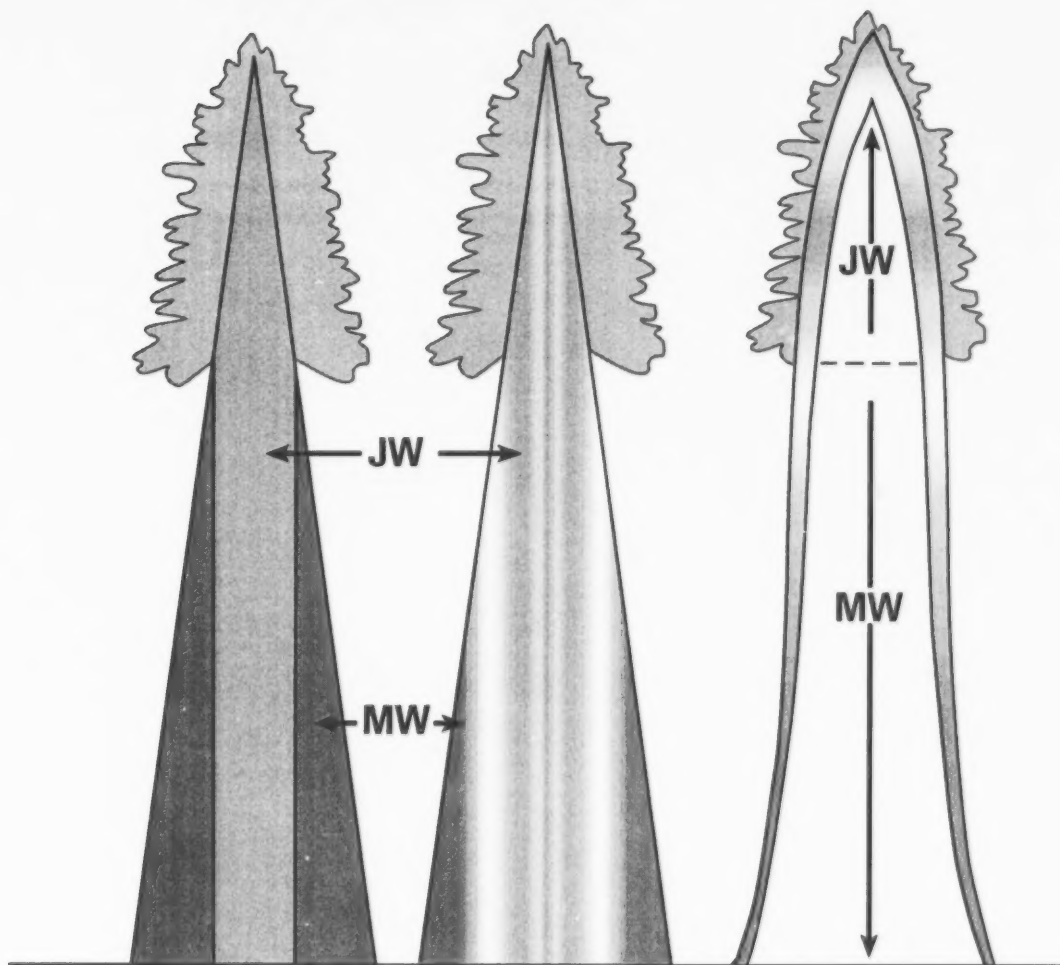
At the outset state that **crown-formed wood** is a much better label than juvenile wood.

Describe crown recession as a function of age and stocking/stand density. Use the lodgepole pine example, where at >2000 stems/ha the branches at breast height died at age 13, and the branches were small in diameter. Conversely, in a 700 stems/ha some branches have >60 annual rings, and they have a large diameter.

The biggest contrast is between an open-grown and a dog-hair-stand- grown tree. Spend some time in drawing out some comments from the class, and refer back to the basics associated with overhead 20. Stem taper and volume are important, but other wood quality attributes should be described next, starting with relative density (from pith-to-bark and from stump-to-top).

Emphasize that there are other measures of wood juvenility, which include the chemistry of wood (lignin, cellulose, and extractives content), fibre length, fibril orientation, which will be described later on.

Juvenile Wood (JW) and Mature Wood (MW)



OVERHEAD 37

The transition from crown-formed wood to mature wood is not sudden, as might be interpreted from the graphical representations. The transition is gradual, as the middle stem profile shows through subtle shading.

A surprising fact emerges when we examine the last complete growth-layer in an 85 year old lodgepole pine (or any other softwood), from the tip of the tree, right down to the stump. The colour coding, from blue to red, represents the transition from the juvenile to the mature phase. That is, wood that was formed in the live crown, and away from it.

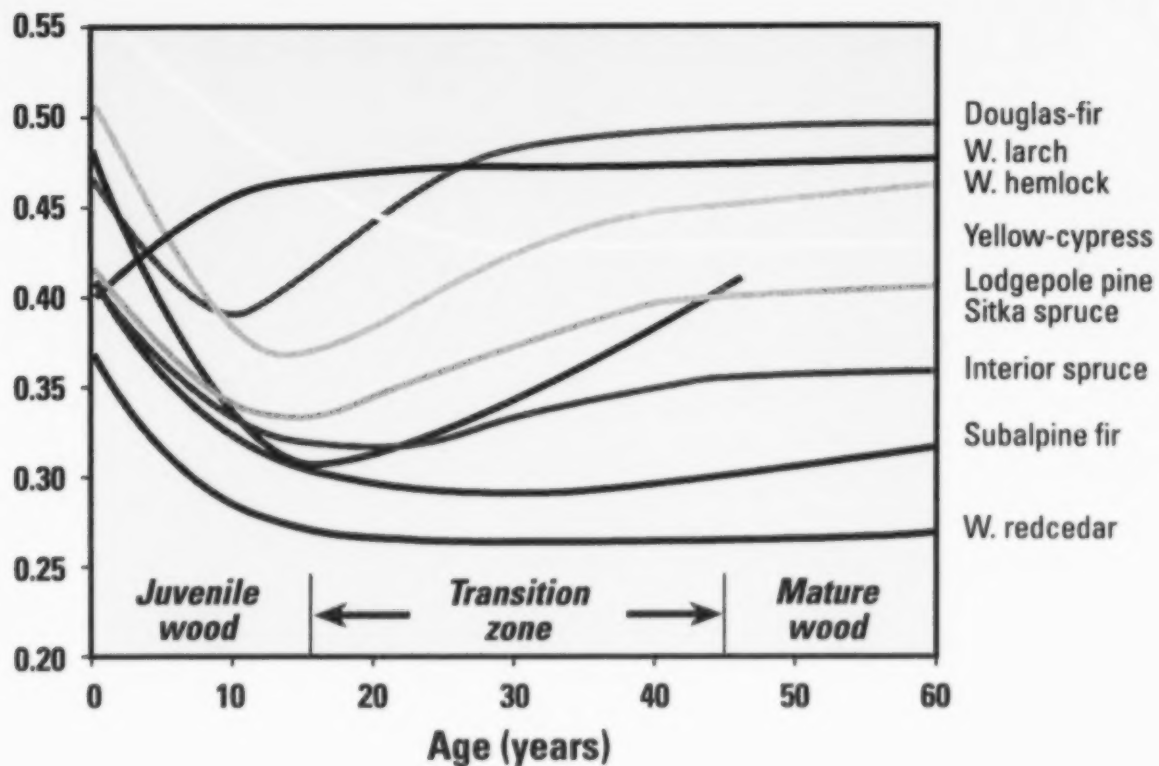


OVERHEAD 38

This overhead provides a visual representation of the extent of juvenile/mature wood in 50 year old Douglas-fir. Juvenile wood in this example is the first 20 years of growth, painted green on the log and lumber ends. On average, these 50 year old trees contained 50% juvenile wood by volume, running from the stump to the top of the tree like a stove pipe.

Log ends (and the resultant lumber without end-trim) were colour coded to enable researchers to identify the degree and extent of juvenile wood in each piece of lumber. This was needed in relating strength and stiffness results to visual lumber grades, and ultimately to the impact of the presence of juvenile wood in the piece.

Relative Density at BH of Rapidly Grown B.C. Woods

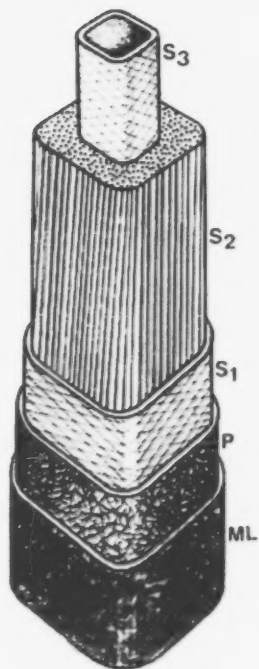


OVERHEAD 39

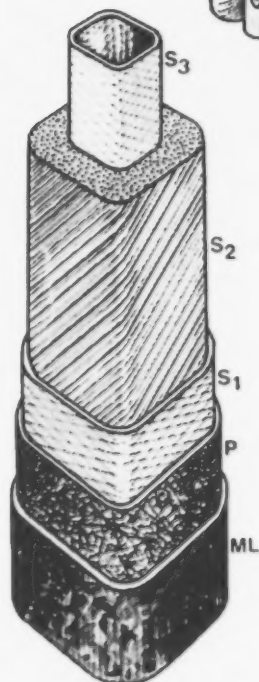
Before showing this overhead introduce the pith-to-bark density trend by dipping portions of a Douglas-fir and a western redcedar longitudinal shrinkage sample (pre-prepared, painted, and marked for this purpose). *Without this introduction (with overhead 37 still on the screen) overhead 38 would be overwhelming and confusing.*

The principal points here include:

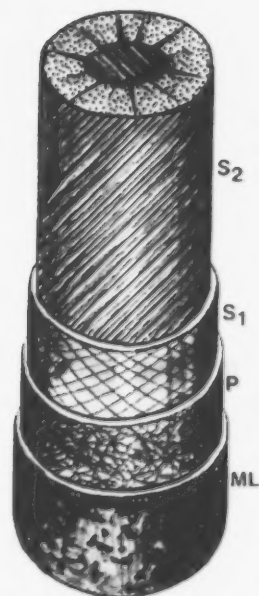
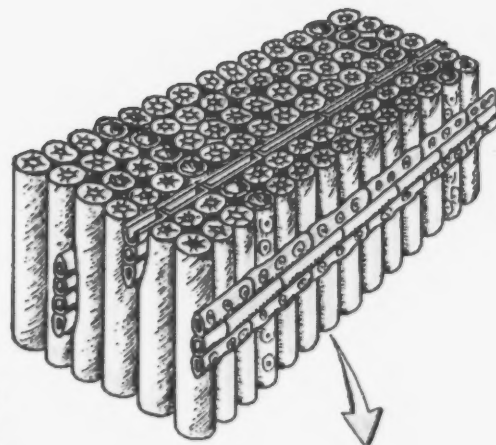
- **these examples are from the most rapidly grown trees we could find in BC in forest environments! THESE ARE NOT RESOURCE AVERAGE TREND-LINES!** Simply, these trees were selected to study potential wood quality problems in rapidly grown second-growth trees.
- not all species have low-density juvenile wood!
- the transition from juvenile- to mature-wood is very gradual!
- these trend lines are for breast height samples!
- the pith-associated high density wood (from 1–5 years) is thought to be the product of mechanical stimulation from the wind!



Mature wood



Juvenile wood



Compression wood

OVERHEAD 40

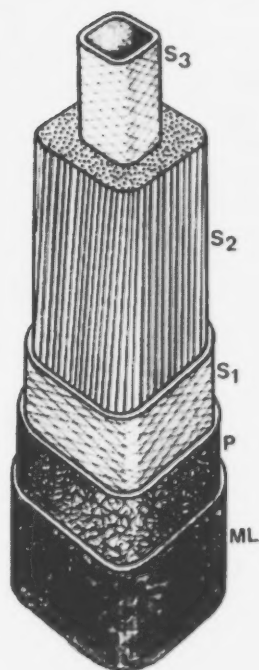
Fibril orientation is another measure of wood juvenility, and in case of Douglas-fir it seems to be in good agreement with the density trends just described, in terms of time interval. This example shows the gradual "straightening out" of fibril orientation from age 1 to 20, from >30 degrees to about 10 degrees.

For background information read pages 18–20 of SP No. 34.

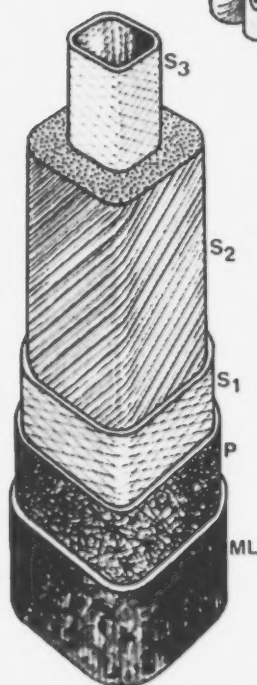
The main point to put across here is that we are looking at submicroscopic structure of individual fibre walls. In addition, although we are describing micro features, they have macro consequences in terms of strength and dimensional stability.

This is a good opportunity to show some examples of Simon Ellis' 1 × 1 clear western hemlock strength results (stable density trends with increasing strength values).

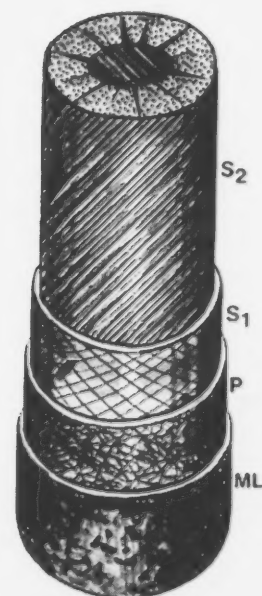
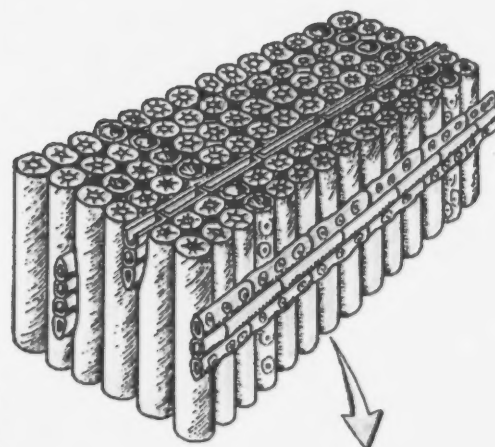
Show 2 × 4 with crook (pith-associated wood on one narrow edge, had greater longitudinal shrinkage than the other edge).



Mature wood



Juvenile wood



Compression wood

OVERHEAD 41

Fibre length is a wood quality attribute that is easily overlooked from the solid-wood products perspective, however, it is very important to the pulp and paper sector.

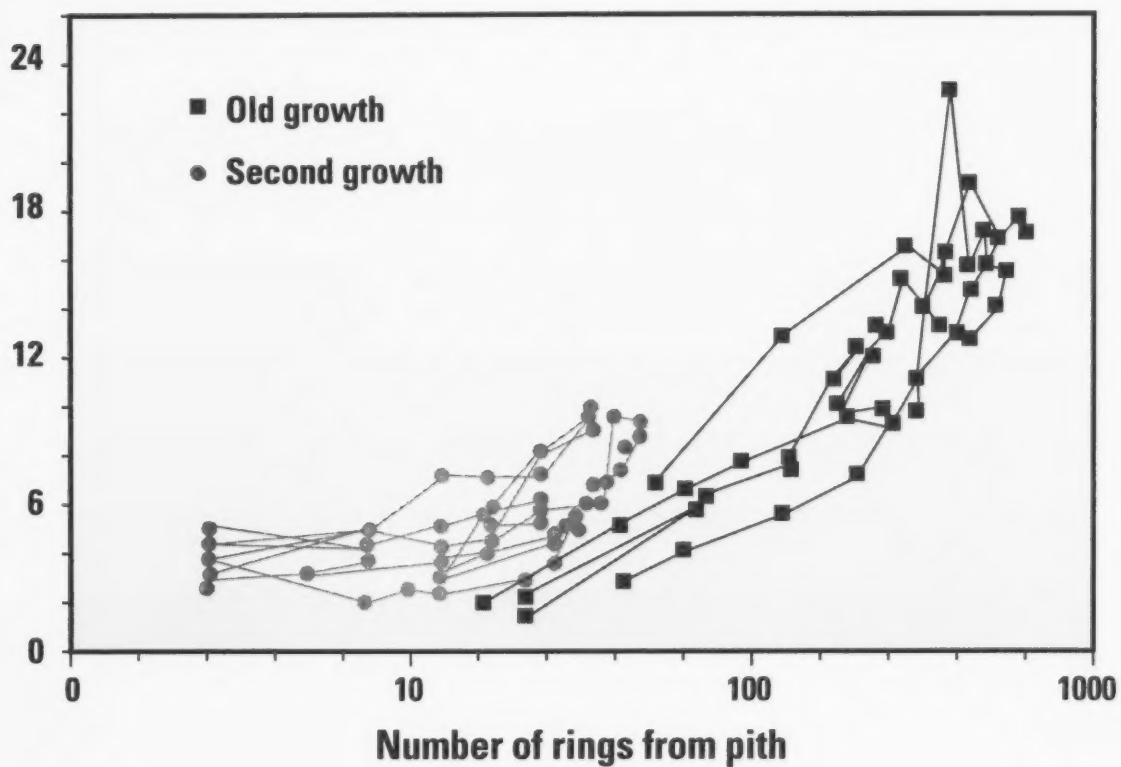
This overhead shows fibre length as a function of age at five height levels in 50 year old Douglas-fir trees (from Forintek's Douglas-fir Task Force). Fibre length was measured for each five-year interval for the first 15 years, and in 10 year increments thereafter. Rapid increase is evident for the first 25 years of growth at all height levels; this levels off gradually, as shown here. With the exception of the BH sample (where fibre length is about 15% shorter), trend-lines are very similar at the other four height levels.

Based on work done to date, it is likely that in all Canadian softwoods fibre length is shortest next to the pith at all height positions in the stem, and it increases gradually outward with age. This means that sawmill chips taken from tree tops, thinnings, and from peeler cores will yield shorter fibres (by at least 1 mm) than chips taken from the outer parts of logs (like sawmill slabs and edgings).

Other researchers have reported a close correlation between fibre length and fibril angle, linking increased fibril angles with shorter fibres; contributing to the lower strength and stiffness of crown-formed (juvenile) wood.

Western Redcedar

Ethanol:Benzene extractives (%)



OVERHEAD 42

This overhead shows why we see hollow western redcedar logs on logging trucks during our travels in the province. Younger wood, like the first 50–100 years of growth in this example, does not have as much extractives as the older wood (>200 years in this example). The results of this work also suggest that a certain loss in extractives occurred in the innermost heartwood of the old-growth trees, particularly for the first 100–200 years.

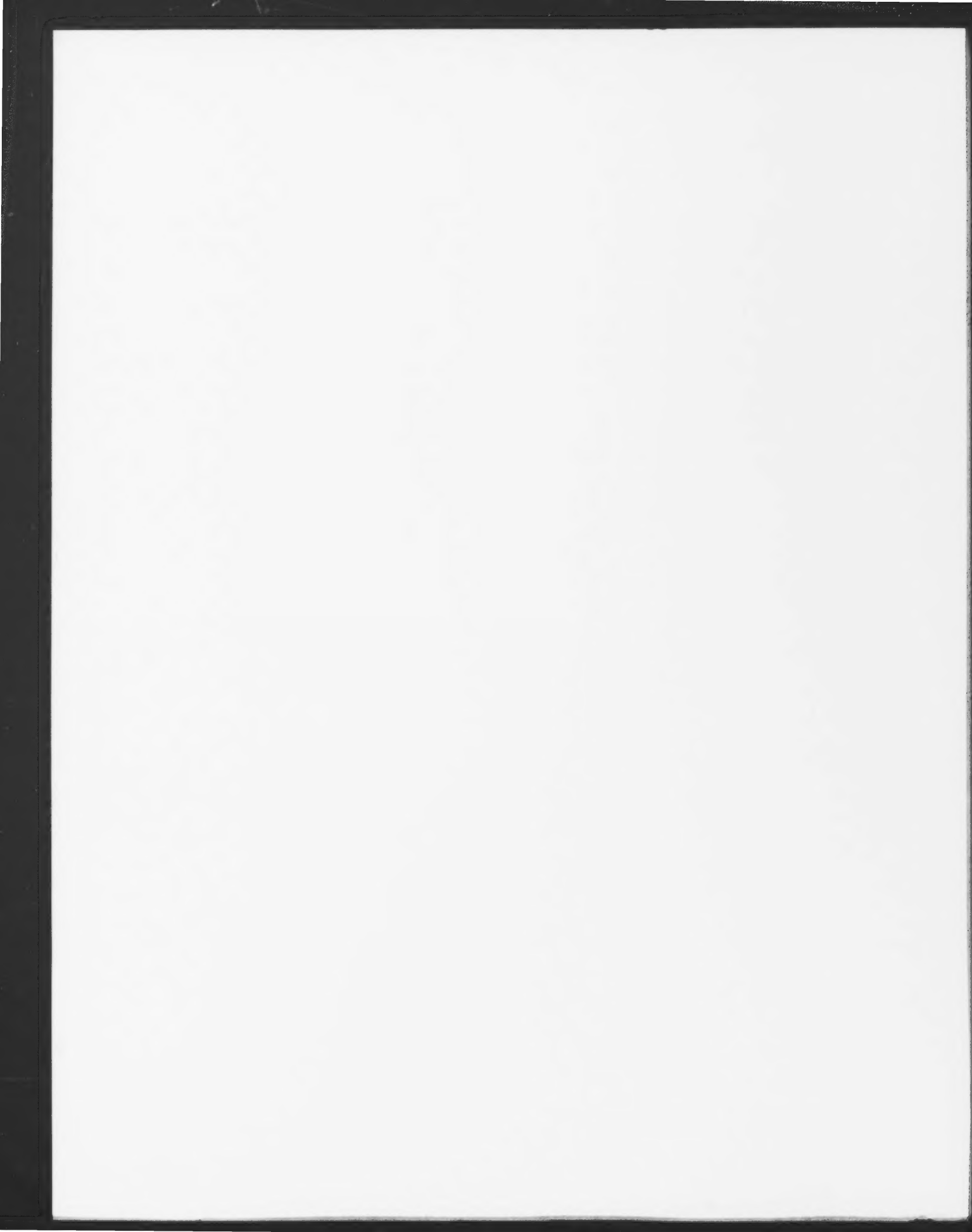
Consider also the large amount of extractives in the >300 year old wood; 16–18% by weight! Every 6 kg of wood contains about 1 kg of extractives!

Interestingly, **extractives** do not figure in the chemical composition of wood, because by definition they are extraneous substances in wood.

Extractives are formed and deposited in cell cavities and cell walls at the time when sapwood “dies” and turns into heartwood. Extractives often impart significant colour and decay resistance to wood. They can be put into solution, using neutral solvents (not acidic or basic) like water, alcohol, cyclohexene, etc. In fact this is what happens when we make tea or coffee; we drink extractives dissolved by hot water.

When woods are naturally resistant to decay and insects, it is attributable to the toxic and repellant nature of their extractives. This is the case with western redcedar and yellow-cypress.

In western redcedar thujaplicins are responsible for the fungitoxic nature of heartwood. Thujic acid has juvenile hormone properties against a variety of insects, while methyl thujate is responsible for the odour of the heartwood. Plicatic acid is responsible for the health effects found in some workers.

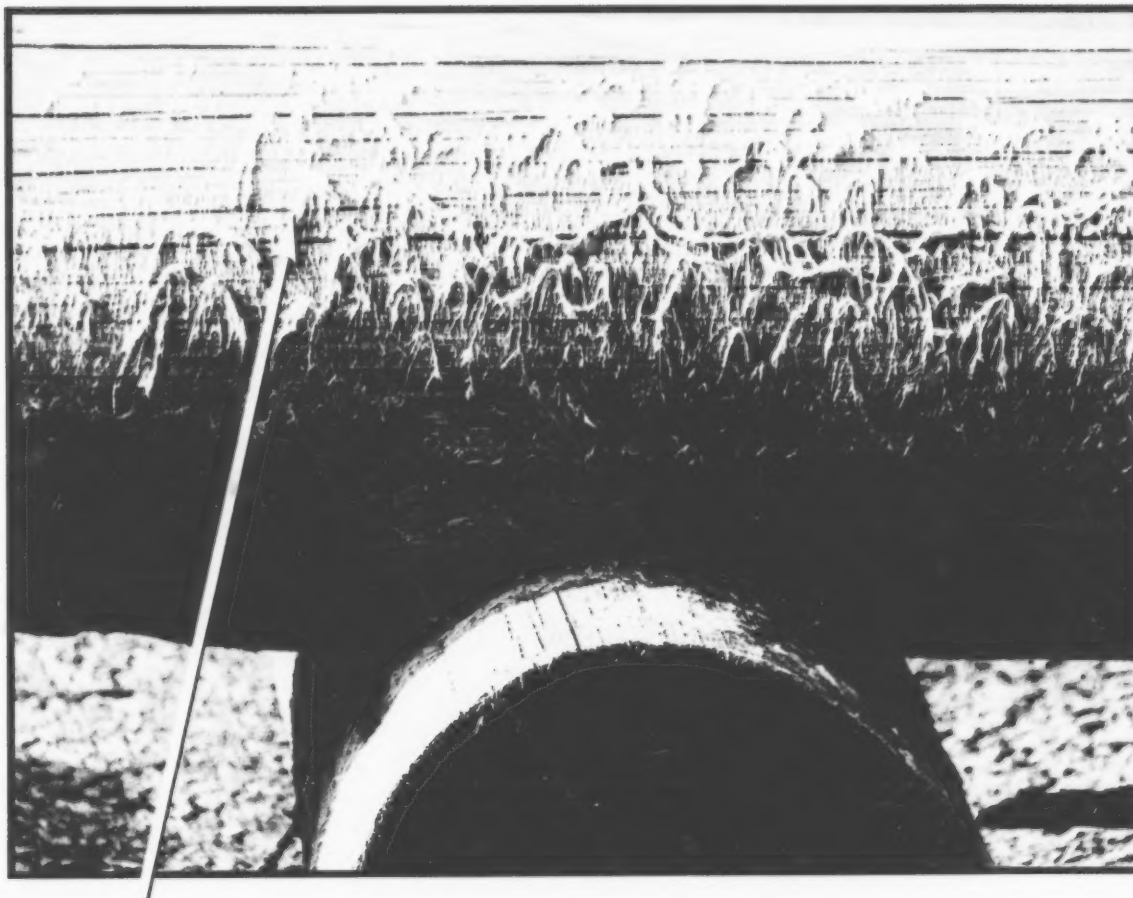


OVERHEAD 42A

Unfortunately, there can be one major problem with these extractives in certain situations because they are water soluble. My colleagues at Forintek studied barn shakes on an experimental roof, at UBC's Malcolm Knapp Research Forest at Haney, and found 25%, 90% and 100% reduction in **thujaplicins** in the exposed butt regions after 1, 3 and 5 years exposure, respectively. This leaching explains why in service decay starts in the butts, and progresses upwards through the shake or shingle. It must be emphasized that these problems can develop only in extremely wet and warm climates, when houses are shaded by trees, litter accumulates on the roof, and the shakes remain moist almost year-round.

For these reasons even western redcedar shakes and shingles should be protected in climates with high decay hazard, using pressure treatment with chemical preservatives.

Evaluation of chromated copper arsenate (CCA) pressure treated shakes have shown high retention at the butt ends after 11 years of exposure (at Haney).

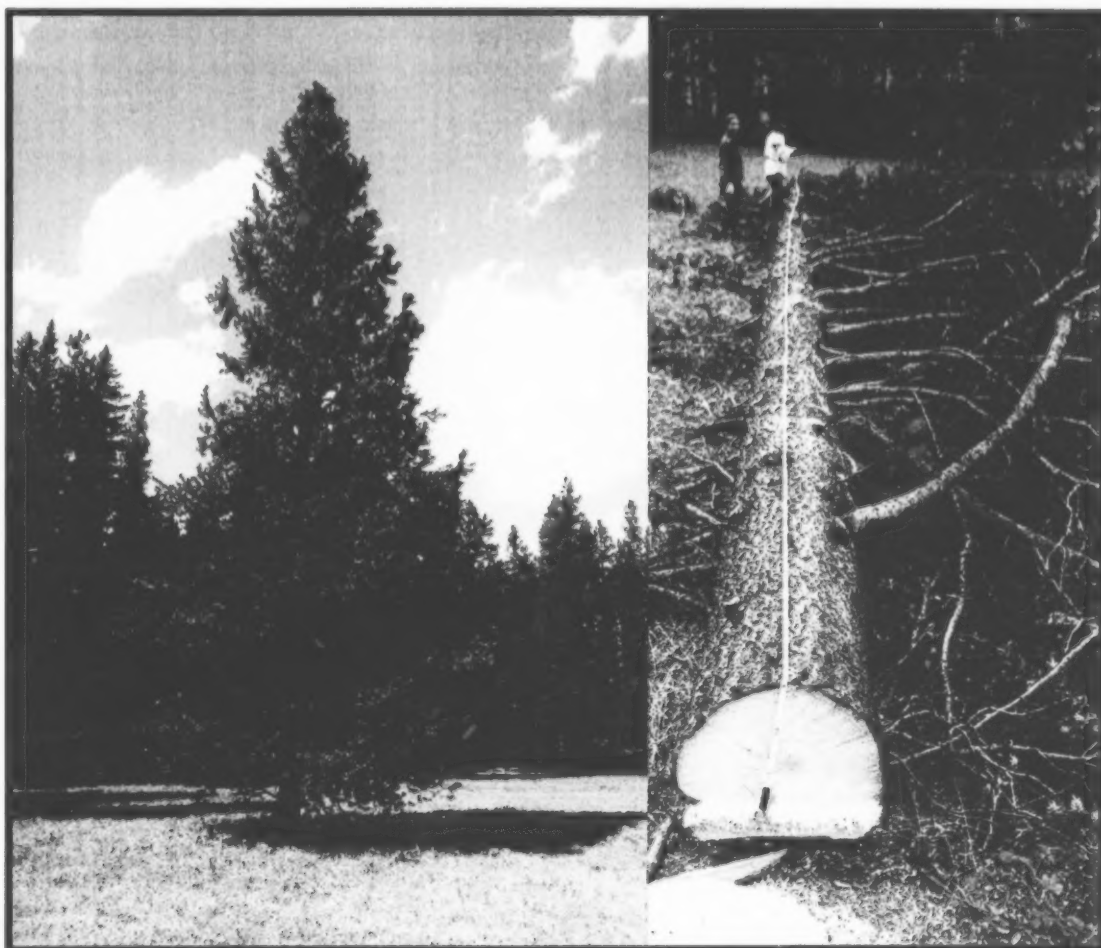


Wood fibres from U.V.
(ultraviolet) exposure
damage from sunlight.

OVERHEAD 43

Because of photochemical degradation by ultraviolet light, about 1 millimetre erosion rate was documented in eight years for untreated shakes with a southerly exposure at the UBC test site. This erosion rate was reduced to less than one-fifth with CCA preservative.

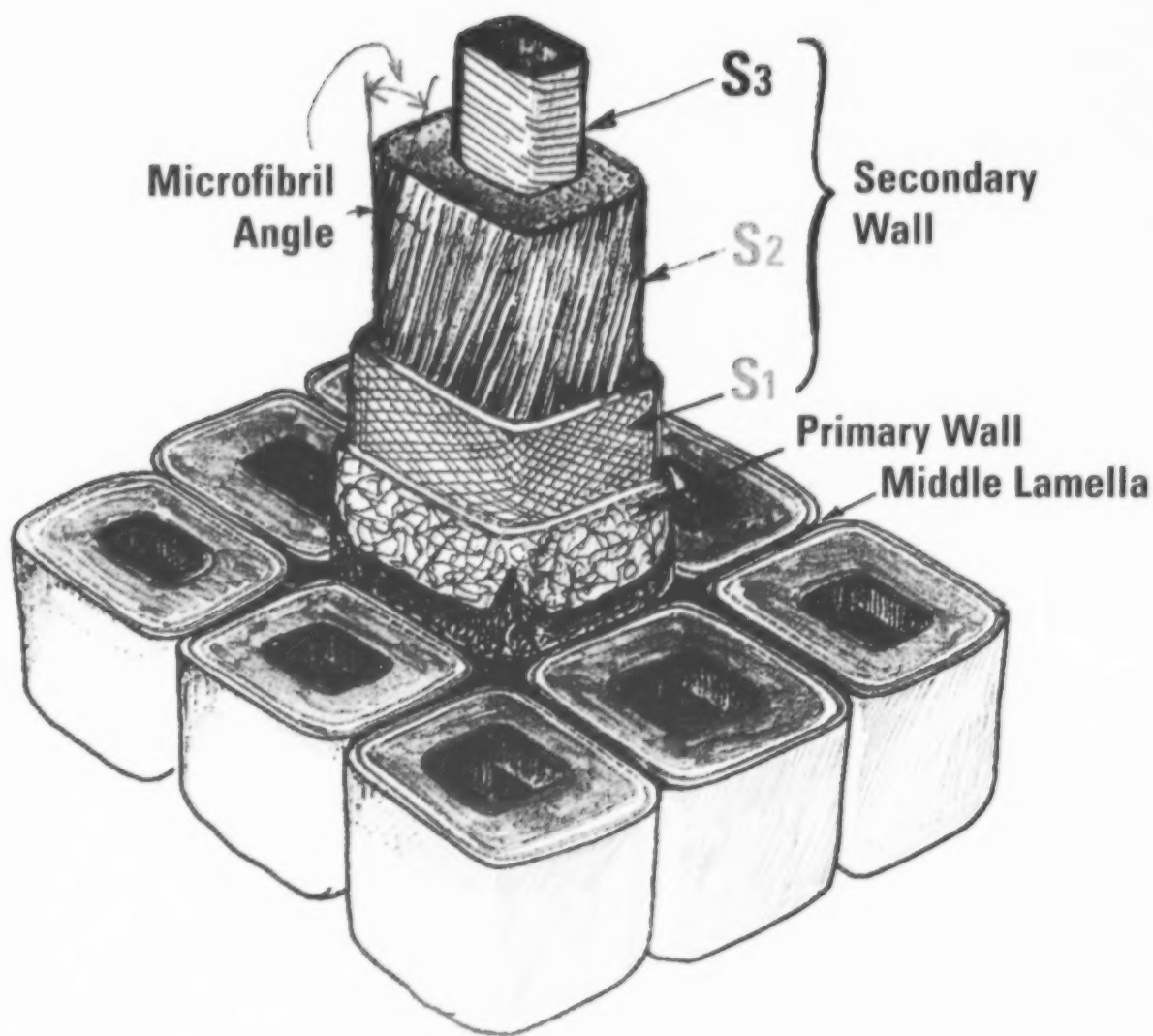
This Douglas-fir bumper-log is from the parking lot at the Mesachie Lake Research Station. Note fibre bundles washed by rainwater, and trapped on slivers of wood. Ultraviolet exposure created a slow pulping process, by dissolving the lignin bond between fibres.



71-year-old open-grown
lodgepole pine.

OVERHEAD 44

To close our discussion of crown-formed (juvenile) wood, lets look at a 71 year old open-grown lodgepole pine tree with live crown to the ground, thick branches, and excessive taper.

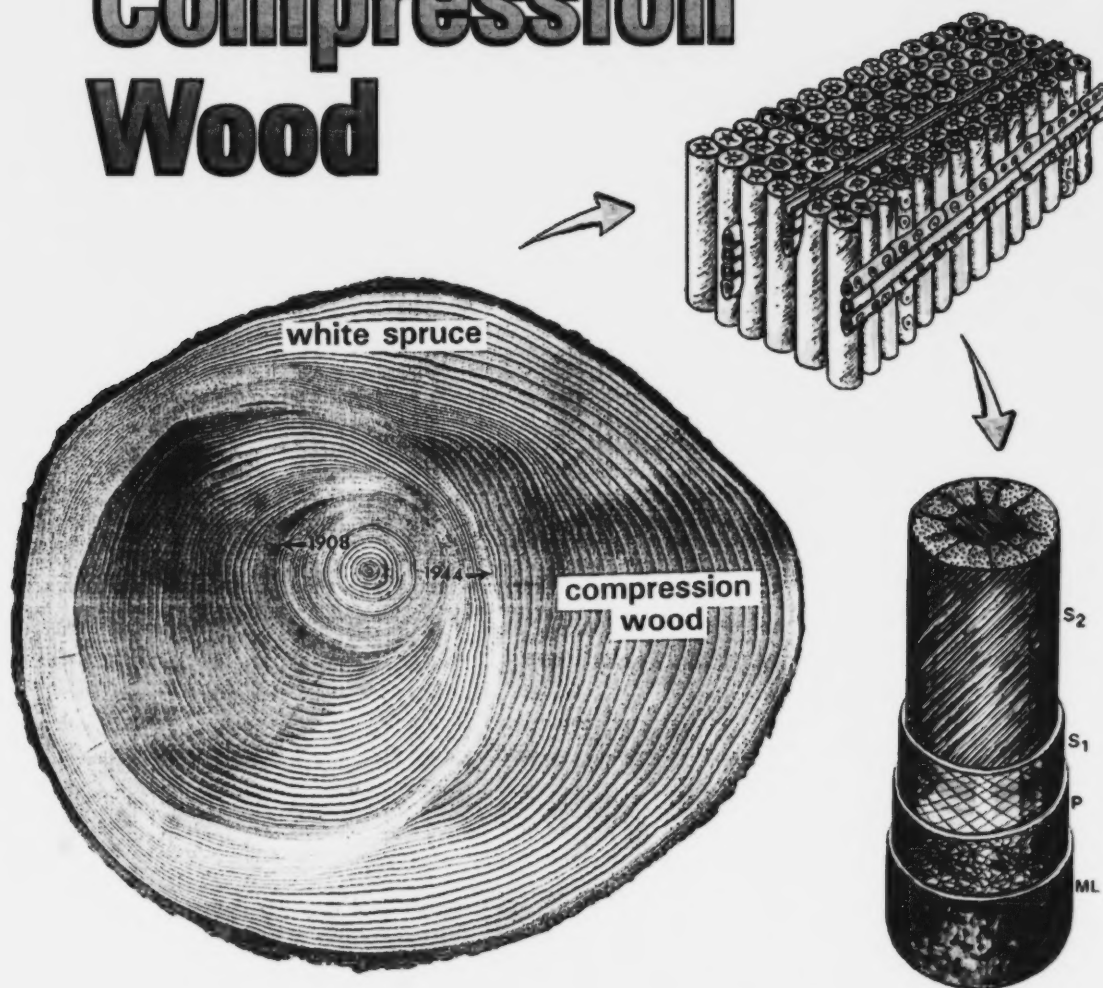


OVERHEAD 45

To introduce the concept of **compression wood**, we should review the layered structure of the fibre wall in **normal wood**.

The lignin-rich middle lamella is the “glue” that holds individual wood fibres together. The primary wall is made up of a loose and random weaving of cellulosic microfibrils, intermixed with lignin. In the secondary wall, made up of S1, S2, and S3 layers, the cellulosic microfibrils are closely packed. The S2 layer is the thickest of the three (from 3 to 15 times thicker in EW and LW), as a result has the greatest impact on strength and shrinkage/swelling. As discussed earlier under crown-formed wood, particularly important is the orientation of microfibrils in the S2 layer.

Compression Wood



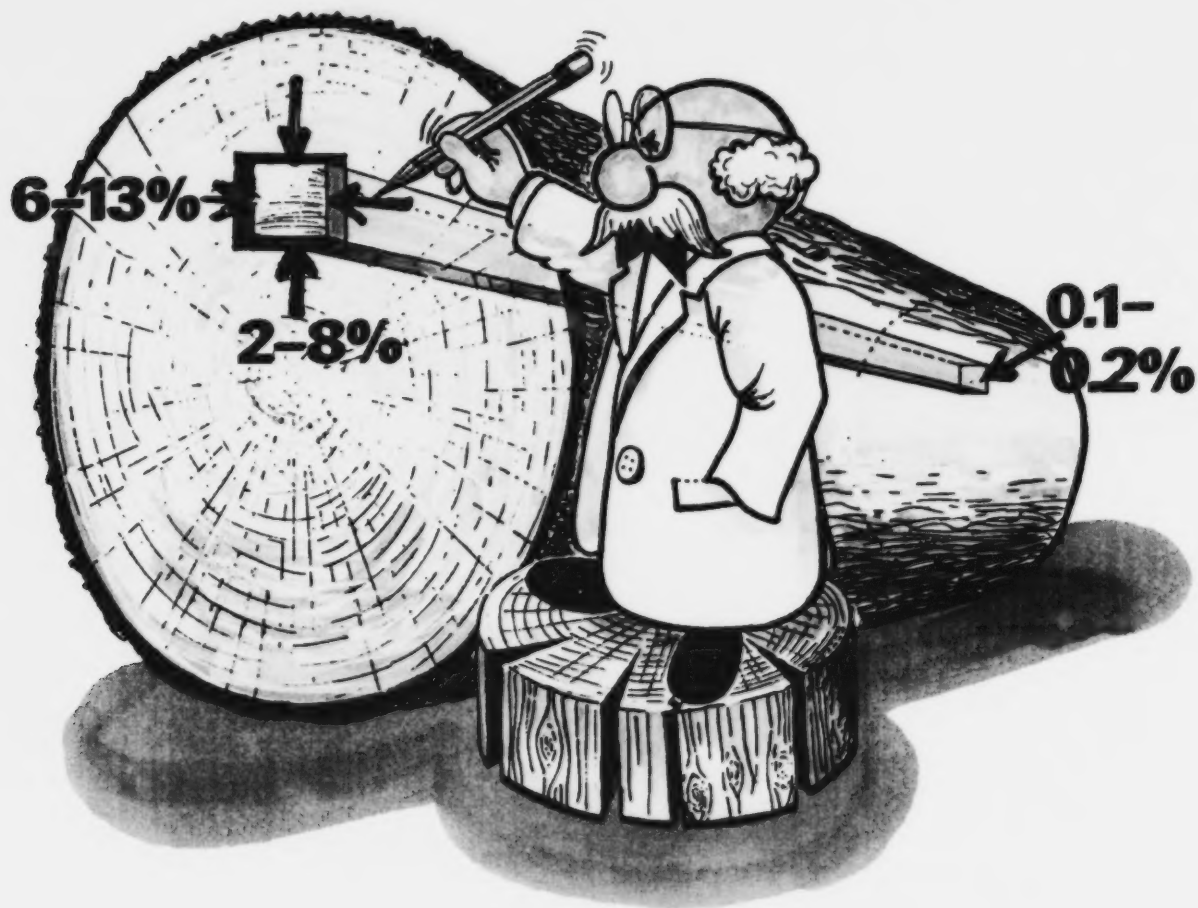
OVERHEAD 46

This white spruce cross section was collected in the early 1970s in Mackenzie River Valley, NWT, for studying landslide activity in the Mackenzie Valley Pipeline corridor. This tree was growing in the upright position from 1876 to 1908, when a landslide pushed it to the left into a leaning position. In 1944 the tree was tilted to the right by another landslide event. Note that there are the same number of rings in the compression wood zone as in the opposite wood zone.

In cross section, compression wood fibres are always rounded, leaving voids (intercellular spaces) where the fibres come together. Compression wood annual rings seem to be composed entirely of latewood, and therefore the wood is very dense. Unfortunately, compression wood is very weak because of the 45 degree microfibril orientation in the S2 layer. Microscopic examination of the fibre wall reveals that the S3 layer is missing. Furthermore, there are deep helical checks or separations in the fibre wall, which extend from the fibre cavity right through the S2 layer. It must be emphasized that these are not drying checks, they exist in the wet and living tree. These helical checks contribute to the opaque appearance of compression wood in transmitted light; the helical checks refract light, while normal wood fibres transmit light not unlike "optical fibres".

Discuss silvicultural implications in late-thinning tall, slender trees, that get pushed into permanently leaning position, hence growing "useless" compression wood. Don't do it! Consider ht/diam.!

Typical Shrinkage Values for "Normal" Wood

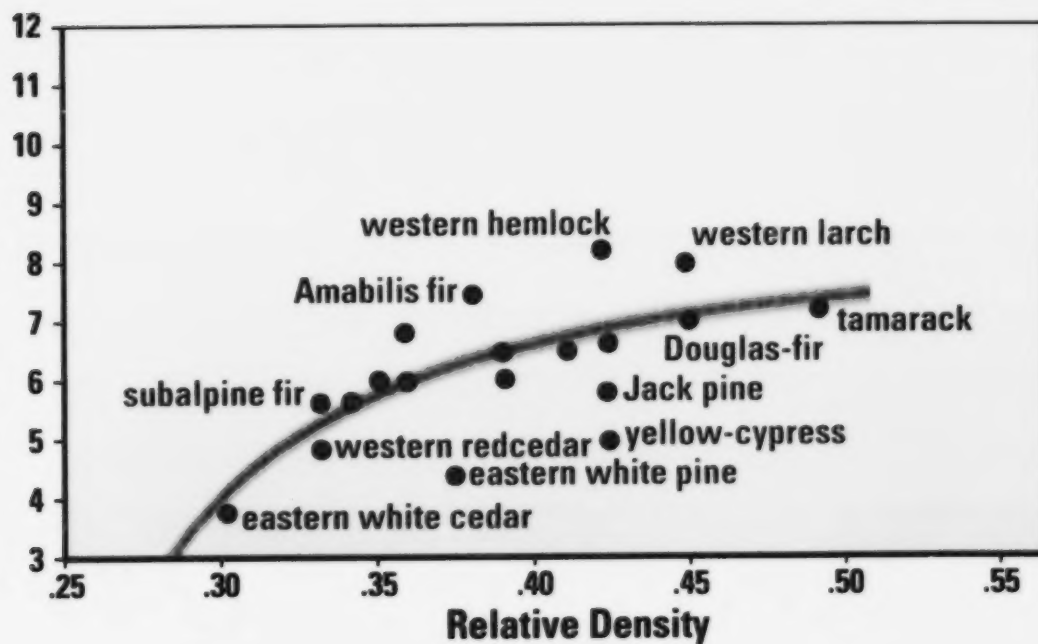


OVERHEAD 47

Typical shrinkage values for "normal wood". Review the anisotropic nature of wood, contrasting edge grain with flat grain. Ask the students for their explanation of nearly 2× shrinkage in flat grain (tangential section).

Ask for examples of end-uses where flat/edge grained wood is preferred. "Hot buttons" include appearance, even wearing, and dimensional stability.

% Volumetric Shrinkage at 12% MC



OVERHEAD 48

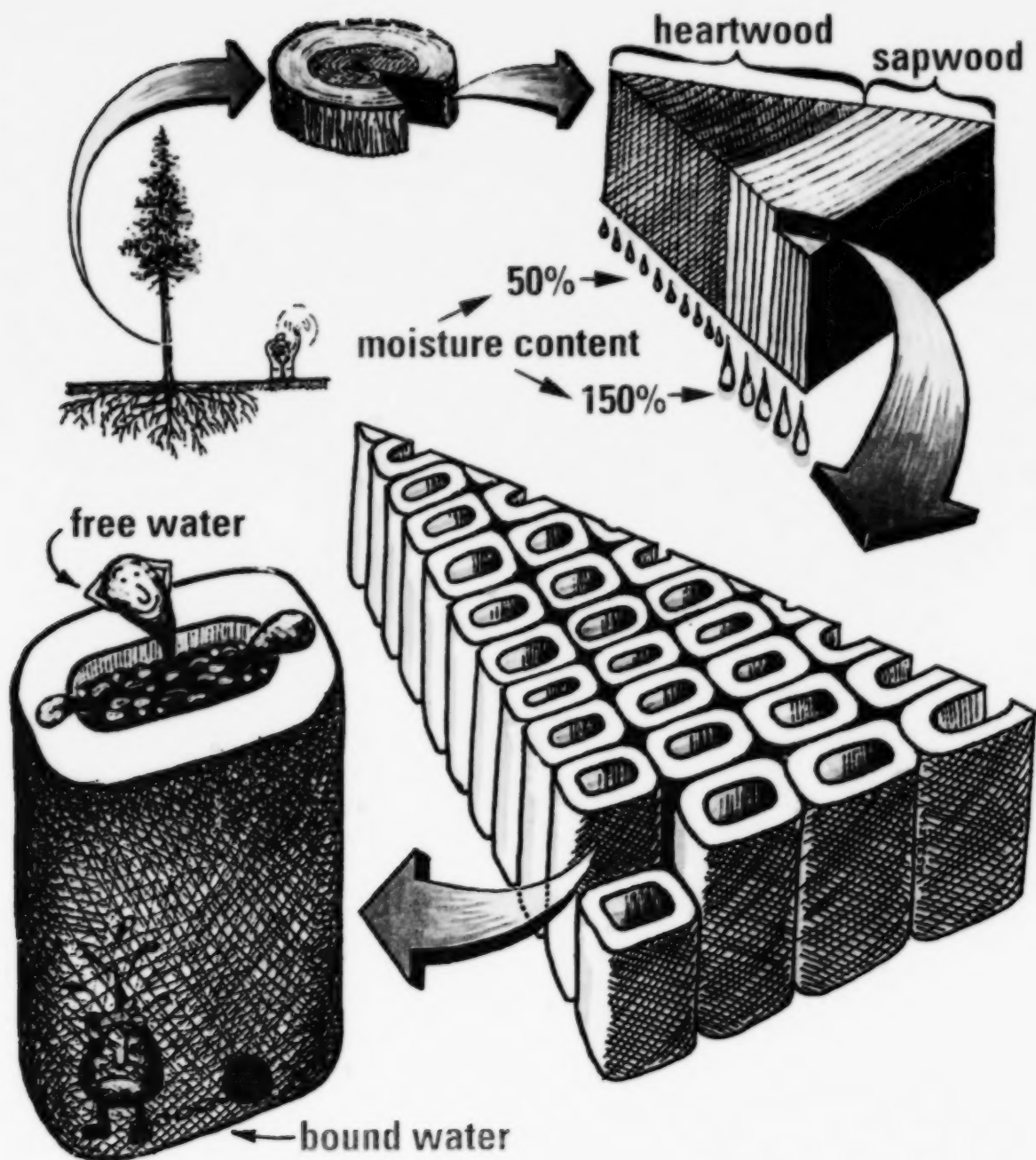
Higher density woods shrink more than light woods, although there are notable exceptions when we zoom in on western hemlock and yellow-cypress. Invite suggestions for rationalizing these differences (extractives, fibril angle, etc.).



OVERHEAD 49

Explain the main reasons for drying wood, and why foresters/silviculturist should concern themselves with lumber drying. The main reason they started drying lumber in the Interior was shipping charges were based on weight. Apparently, it was cheaper to remove the water through lumber drying than paying for transporting the water. More importantly, proper drying provides dimensional stability, and prevents moulding and decay.

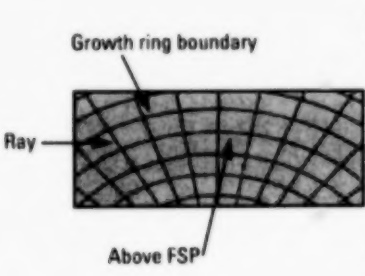
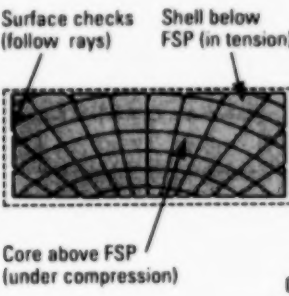
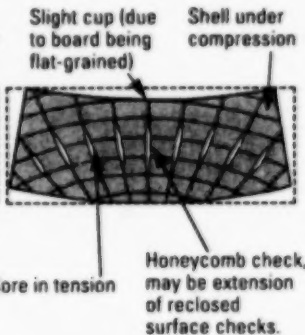
Swedish and German scientists surveyed 100 professional carpenters, asking them to list (in order of importance) the most important characteristics of structural lumber products. Dimensional stability was the number one requirement! The study conclusions and recommendations included the suggestion that no carpenter should be allowed to enter the trade without six months prior forestry experience. Also, all potential foresters should have at least six months experience on a framing crew, or in carpentry.



OVERHEAD 50

To demonstrate the concept of free and bound water, start with two identical dry cellulose sponges. Draw everyone's attention to the identical thickness, width, and length. Put one of the dry sponges into a bucket of water, until it is fully saturated (squeeze it a couple of times). Pull out the wet sponge, dripping water, and make a size comparison with the dry one; it is thicker, wider, and longer, because of its swollen state. If we squeeze the wet sponge, free water pours out. Similarly, we can squeeze out free water from wet wood, as in hitting green lumber with a hammer in nailing; we can see water spurt out (and sometimes feel it on our face). Now squeeze out all the water from the wet sponge, by wringing as hard as you can. One can even use dry paper towels to wick water away. A point will be reached when no more water can be squeezed or blotted from the sponge, yet it remains flexible and damp to the touch. It is still the same size as was when dripping wet. Therefore, removing free water from wood (sponge) will not result in shrinkage. This state, as in wood, is the fibre saturation point: the fibre cavities are emptied of free water, but the fibre walls are saturated with bound water. Shrinkage starts to happen when we start removing some of the bound water.

The Process of Wood Drying

Drying Stage:	I	II	III
Moisture Condition:	Above fibre saturation point (FSP) throughout: Drying begins with loss of free water from surfaces.	Shell now below FSP, core still above FSP. Core moisture migrates outward to shell.	Below FSP throughout, eventually reaches uniformly low EMC.
			
Stress Condition:	Stress-free	Shell tries to shrink, creates tension across surfaces, squeezes the core into compression. Drying sets shell in oversized condition.	Core now trying to shrink away from oversized shell. Core develops tension, pulls shell into compression.
Defects:	Defect-free	Surface may check; core may collapse.	Surface is casehardened; core may honeycomb.

OVERHEAD 51

Lumber drying is explained in this overhead in three stages: moisture condition, stress condition, and drying defects in the wood.

Don't show this overhead all at once! To start, expose only the title and the boxes on the left-hand side. Explain what is coming and why we aim at defect-free lumber. Next, reveal and discuss the three stages one-by-one.

In this overhead perhaps the most difficult concept to demonstrate is the set condition. One attempt is to place a medium size (length about 19 cm) rubber band over the extended fingers of one hand. Show that there is hardly any tension in the rubber band, it sits loosely over the fingers between the first and second knuckles. This represents a stress-free piece of lumber at stage I in this overhead. Next, double over the rubber band. This causes considerable squeezing over the fingers. This is what happens in stage II in terms of stress condition; the shell is trying to shrink because it is below the fibre saturation point, but the core will not let it happen, because it is fully bulked up (its moisture content is still above the fibre saturation point). This "tug-of-war" between the shell/core, tension/compression results in the shell "giving up, and saying the heck with it, I am going to stay at this size, no matter what happens next". The shell is set.



Wood Quality... Impact on Product Yields, Grades and Value

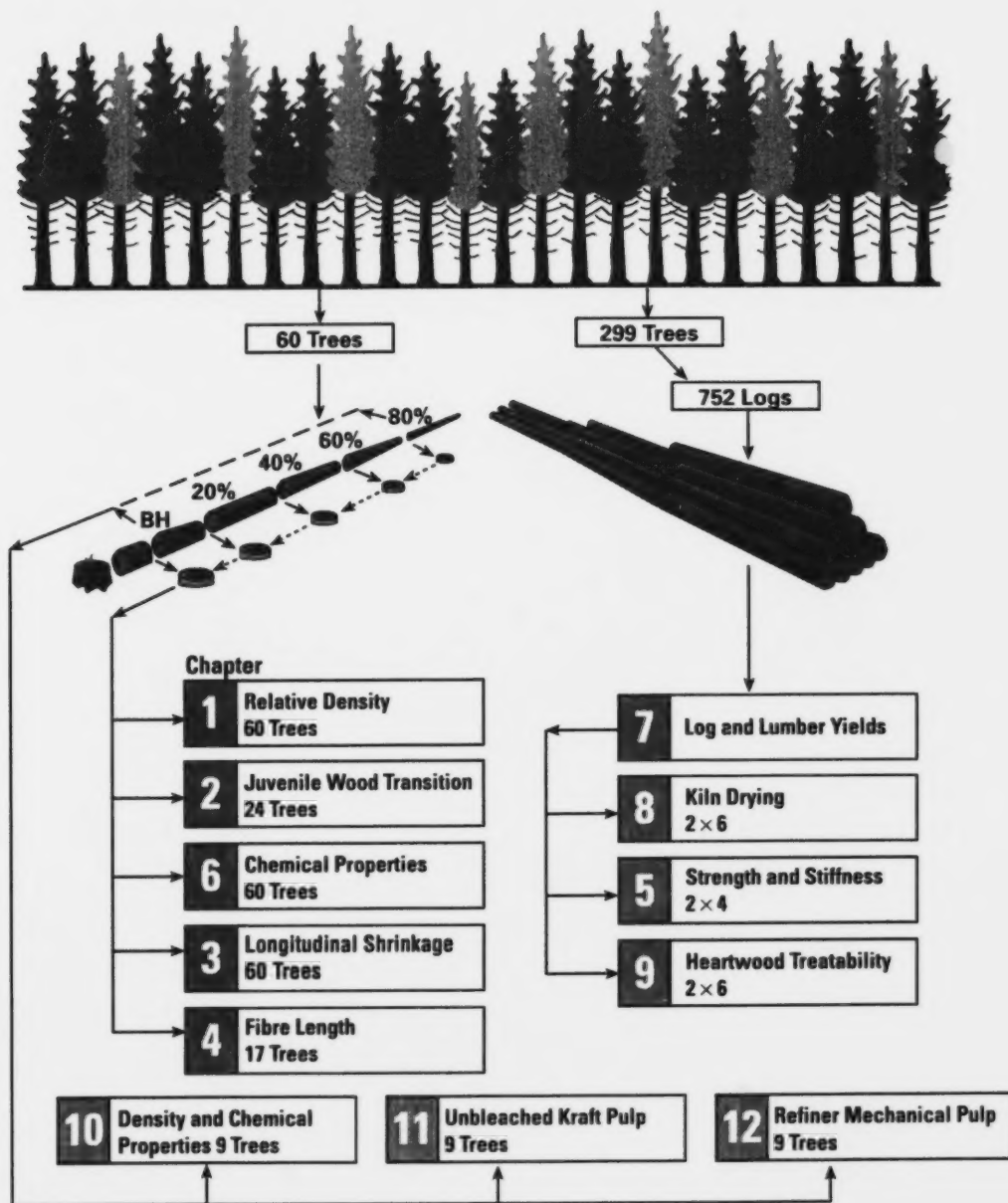
SHRINKAGE OF WOOD

520

OVERHEAD 52

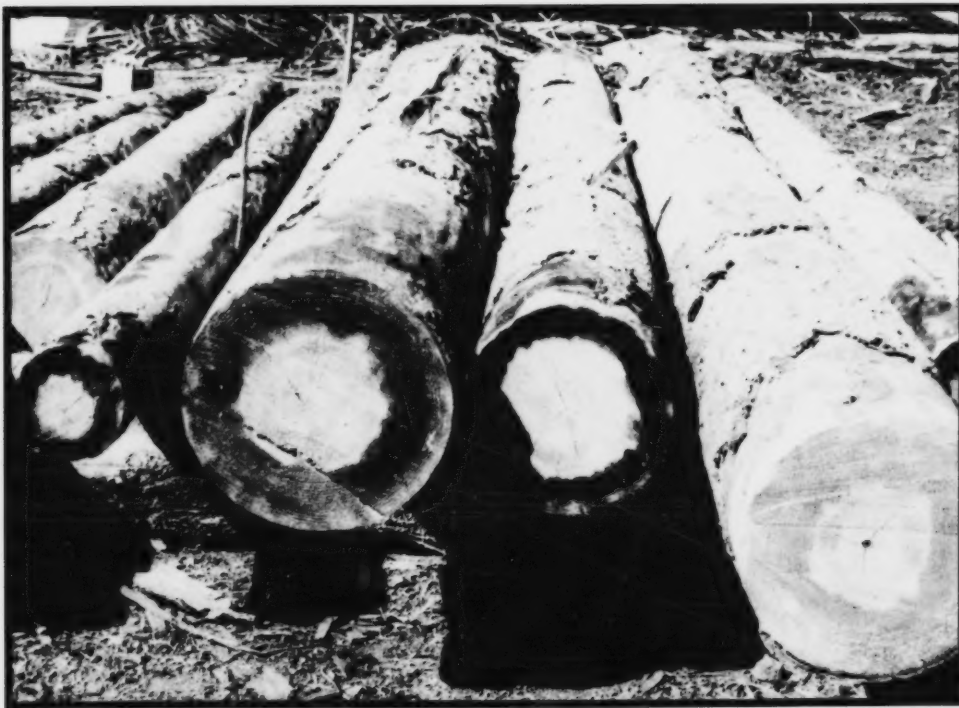
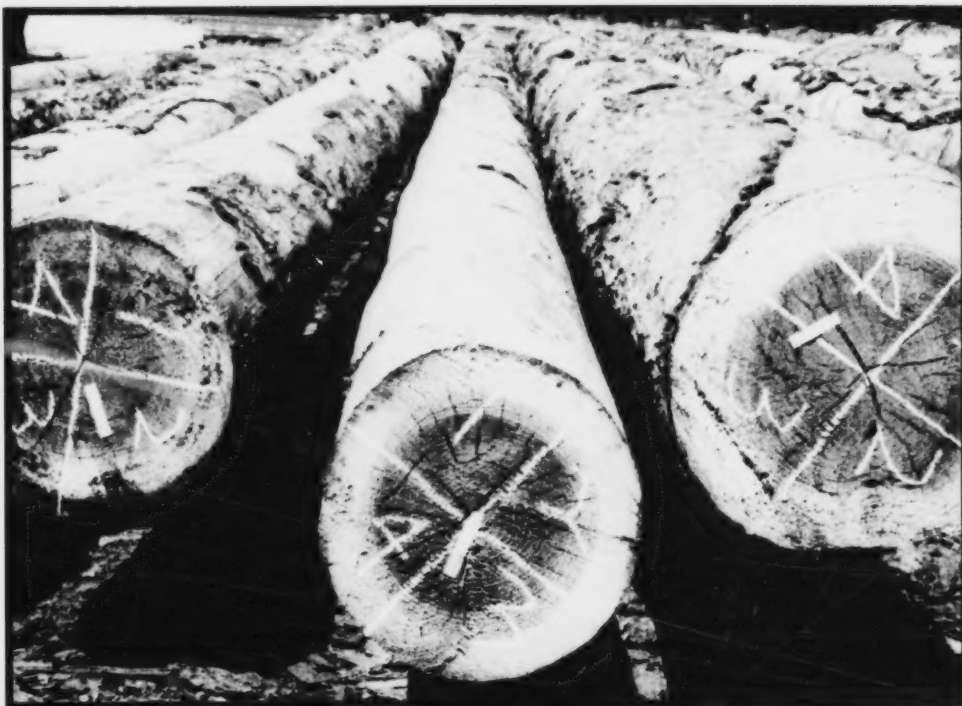
With remanufacturing lumber into secondary high-value products, stress-free lumber is very important. Excessive drying degrade can be very expensive. For example, if a large sawmill were to reduce its drying degrade by 1%, it could result in a \$1,000,000 saving/profit in one year.

Second Growth Douglas-fir Resource



OVERHEAD 53

The Douglas-fir Task Force study trees were evaluated for basic wood properties (Chapters 1–4), lumber conversion (Chapters 7–9), and for pulp and paper manufacturing. This flowchart shows the number of trees and logs studied.



Wood Quality... Impact on Product Yields, Grades and Value

DOUGLAS-FIR TASK FORCE

54 D

OVERHEADS 54 AND 55

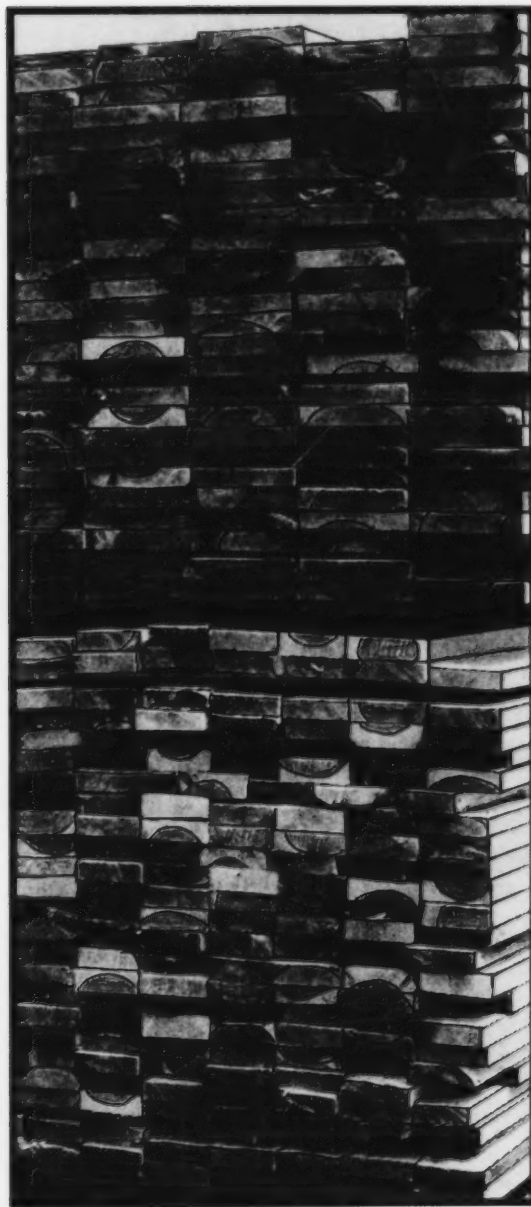
Douglas-fir log ends from 50 year old trees are marked with the first 20 years of growth and with the four quadrants for log diagramming.

Log diagramming is used to document surface indicators of log quality, which include diameter, length, taper, spiral grain, branch stubs and knot indicators, splits, breakage, rot, etc.

To keep track of our logs in a production run, food colouring was used to code log numbers (in groups of five) as they entered the sawmill. At strategic locations in the mill, additional matching colour was sprayed on each piece of lumber. This strategy, along with no end-trimming, allowed the proper identification of each board from each of 752 logs and 299 trees.

The dark centre-disks on log ends show the first 20 years of growth (juvenile- or crown-formed wood), which made up one half of the stem volumes.

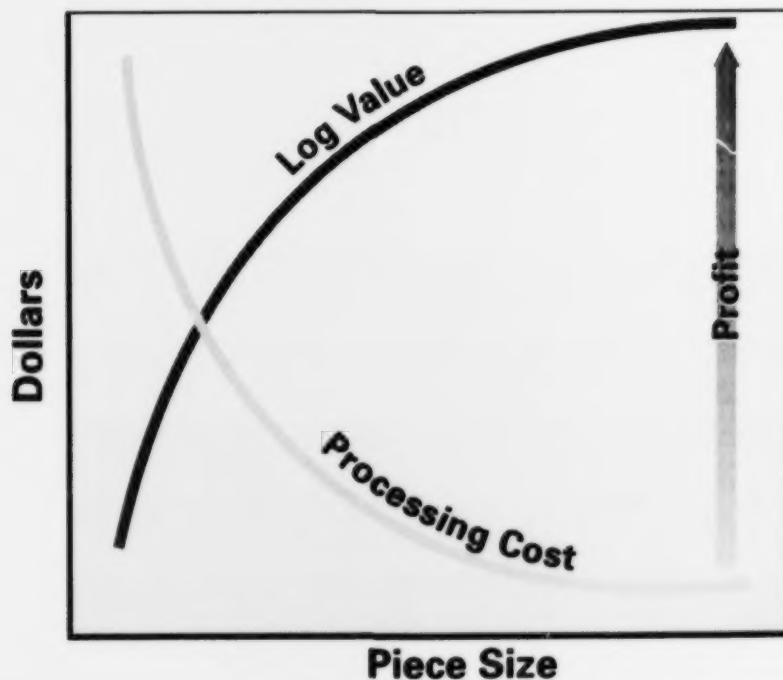
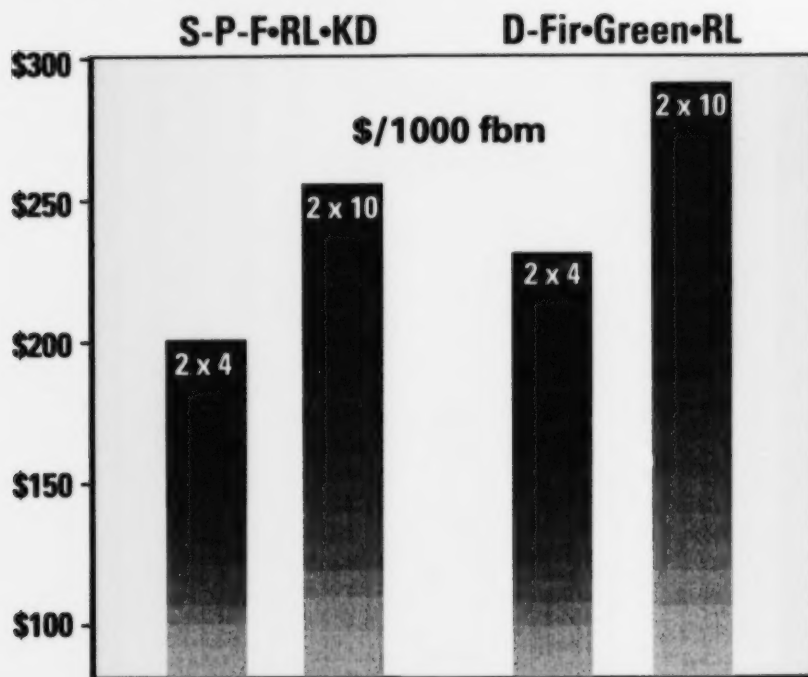
“Rainbow lumber” shows part of the end products from 50 year old second-growth Douglas-fir.



OVERHEADS 54 AND 55

See notes on previous page.

Size Premium



Wood Quality... Impact on Product Yields, Grades and Value

DOUGLAS FIR TASK FORCE

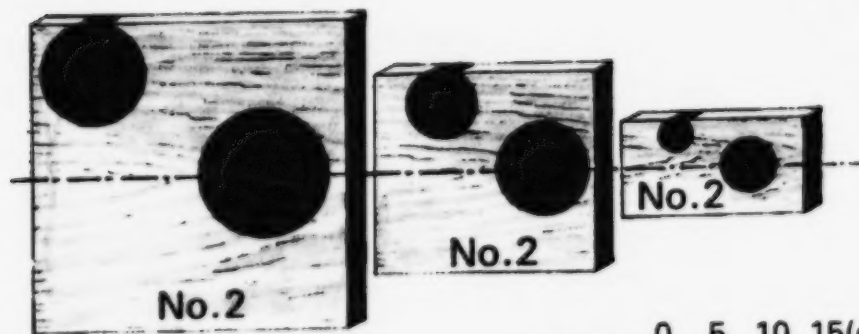
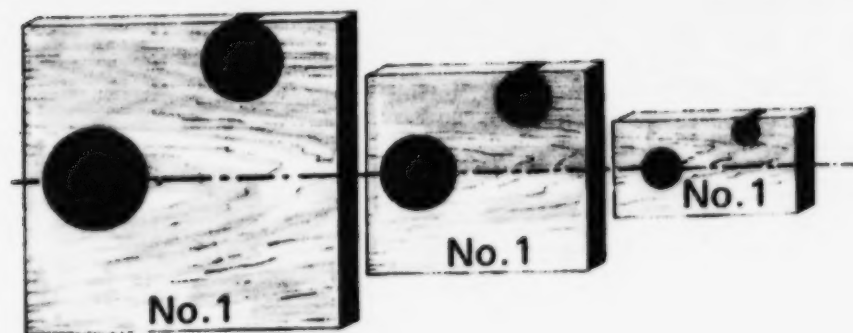
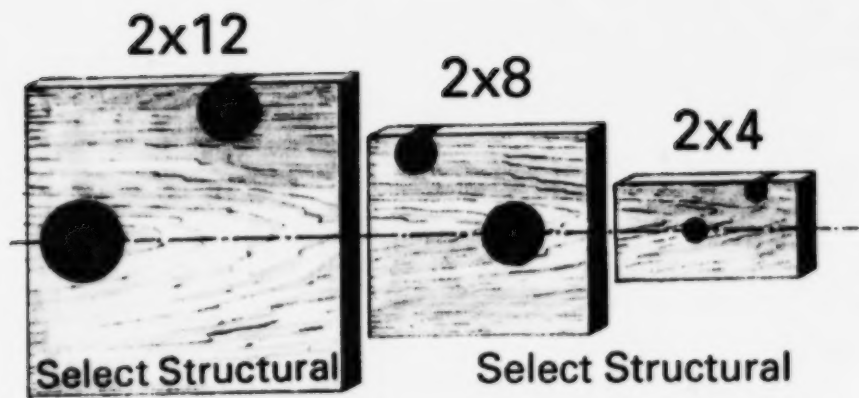
100%

OVERHEAD 56

Lumber prices reflect product quality differences. Price premiums have been a reality for wider widths for many decades. Some argue that in the future this not will be the case. What do you think? and Why? Why is Douglas-fir lumber more expensive than S-P-F?

Log values increase with increasing piece size. Conversely, processing costs decrease with increasing piece size.

Refer to sawmill study example where they cut on average 19 cm and 24 cm diameter logs. With the 24 cm logs lumber recovery factor (fbm/m³) was up 7%, while productivity was 28% higher (than with the smaller logs).



Scale: 0 5 10 15(cm)

OVERHEAD 57

In visual lumber grading **knot size** is just one of the many variables that determines lumber grade. This illustration shows that as piece size increases, so does the maximum knot size allowed in each grade. For example, if the No. 2 2×4 could have been cut into a 2×8 , it would have made the top grade, Select Structural. Incidentally, some of our 50–100 year old dog-hair stand lodgepole pine are smaller in diameter than the maximum knot size allowed in the No. 2 2×12 !

Of course, the critical factor in these grades and sizes is the amount of clear fibre that has to carry the load.

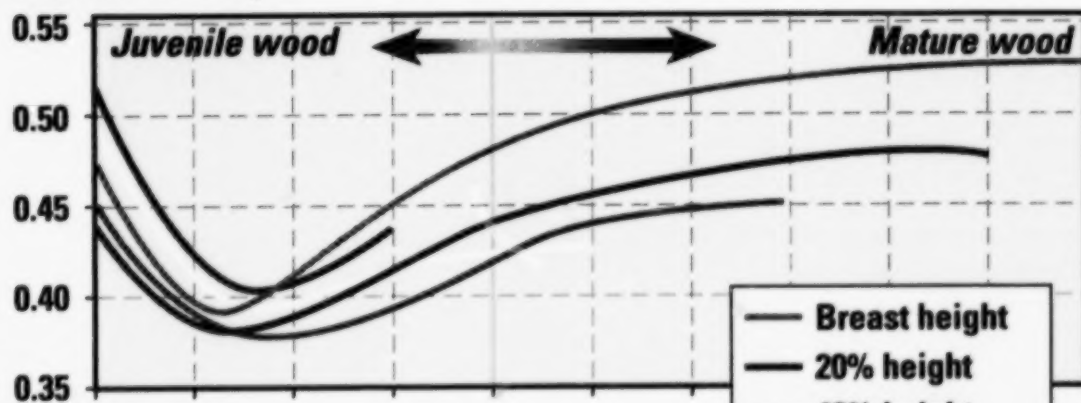
Other lumber grade determinants include: number of rings per inch, pitch and bark pockets, slope of grain, decay, insect holes, wane, etc.

In **joinery grades** (wood destined for door, window, furniture, etc. manufacturing) maximum knot size allowances are much more stringent, and a distinction is made between live and dead knots. Demonstrate these points with props.

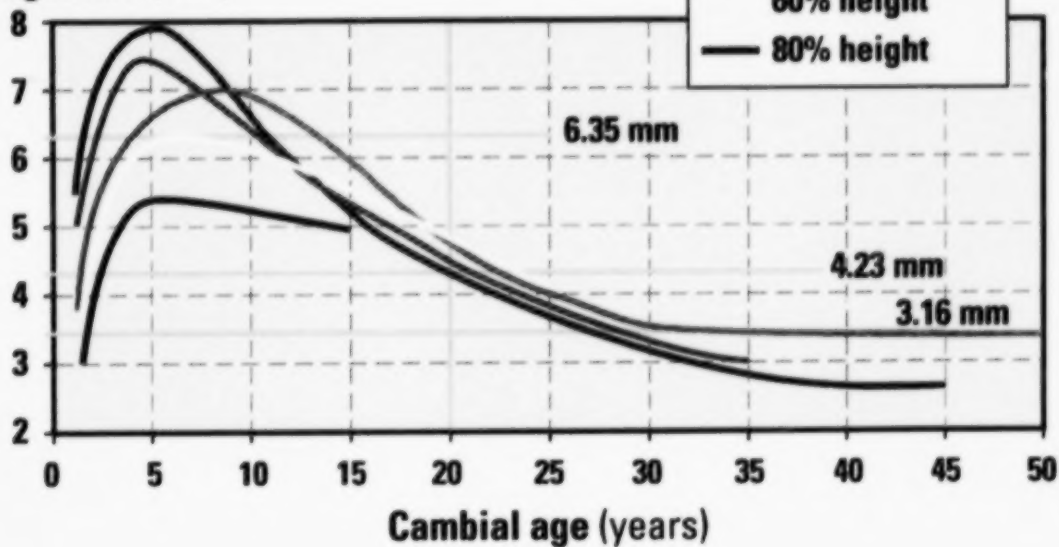
For the 299 Douglas-fir trees, in the task force study, over 100 000 knots were measured. The overhead shows the frequency distribution of knot size, and averages.

50-year-old Douglas-fir

Relative density



Ring width (mm)



OVERHEAD 58

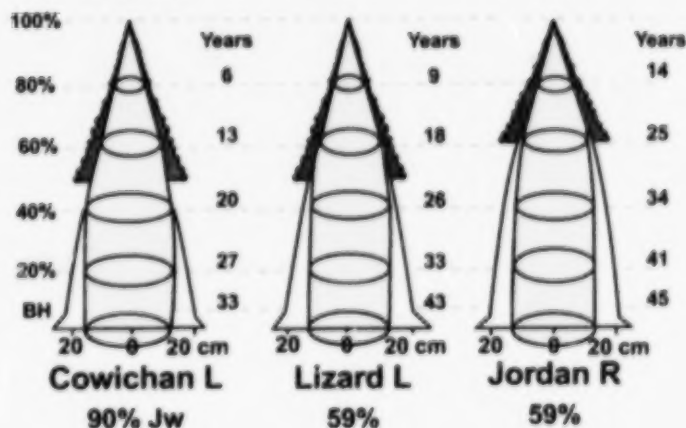
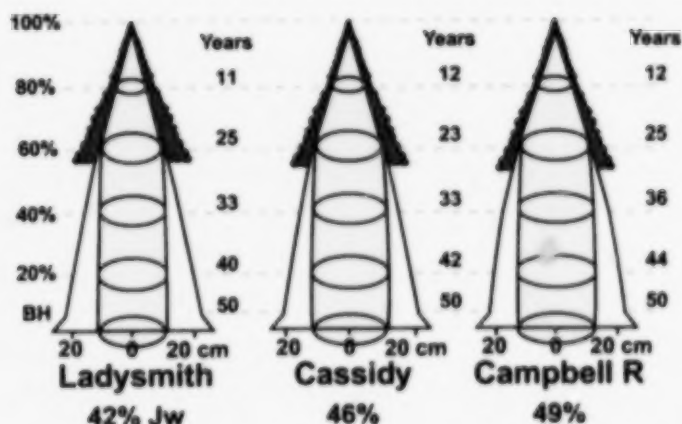
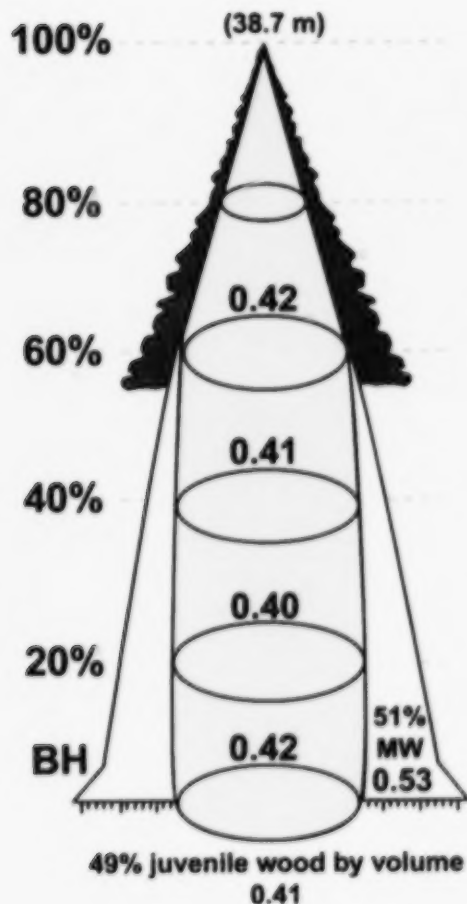
Yearly ring density and ring width trend-lines are shown here for five sampling heights, from BH to 80% tree height.

Note the following:

- With the exception of the 80% sample (because of mortality, by age 50 the top of the tree is growing in a more open environment?), wood relative density at any given age is highest at stem base.
- The higher density at 80% height could be the result of mechanical stimulation from the wind, as are the pith-associated rings at all height levels. Invite opinions from the class.
- Old-growth standard of 0.45 relative density is reached at BH at age 15, at 20% at age 22, and at 40% at age 30. At 60% height the trend-line flattened out at about 0.425.
- Minimum ring density at all sample heights was reached between age 5–10, about the same time as maximum ring width.
- From age 11–13 onward these rapidly growing trees produced more than four rings per inch (the minimum requirement for visual structural visual grades).
- From age 22 and 30 onward, these trees produced “medium” and “fine” grained wood, respectively.

Juvenile Wood Cylinder

First 20 Years of Growth in 50-year-old Douglas-fir



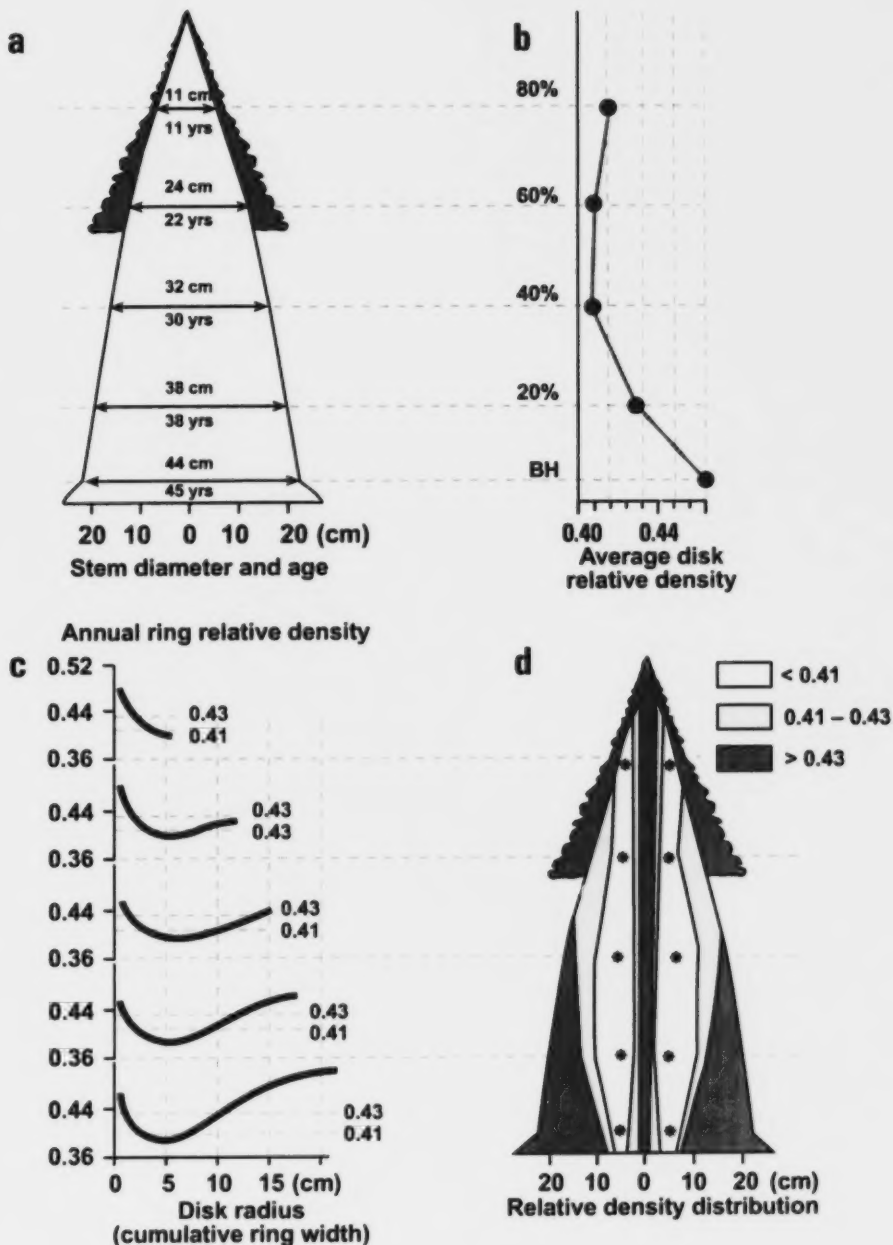
OVERHEAD 59

Tree profiles and the size of live-crown were drawn to scale.

Note:

- About 45 % live crown for 50 year old trees at 530 trees/ha.
- Even at age 33 at Cowichan Lake, the average live crown was 50%.
- Juvenile wood (crown-formed wood) was defined as the first 20 years of growth.
Note cylindrical shape.
- On average, juvenile wood had 0.41, and mature wood had 0.47 relative density.
- Mature wood resides below the live crown.
- The youngest stand was 33 years old at Lake Cowichan, and it had 90% juvenile wood.
The other five stands, from 43 to 50 years of age had 42% to 49% juvenile wood.

Diameter, Taper and Density Distribution in Douglas-fir



OVERHEAD 60

On average, these trees grew 1 cm in diameter each year, at all height levels (panel **a**). **Highest** density wood is in the bottom half of the tree (panel **b**). Top half is not unlike lodgepole pine (0.41), or western hemlock (0.42).

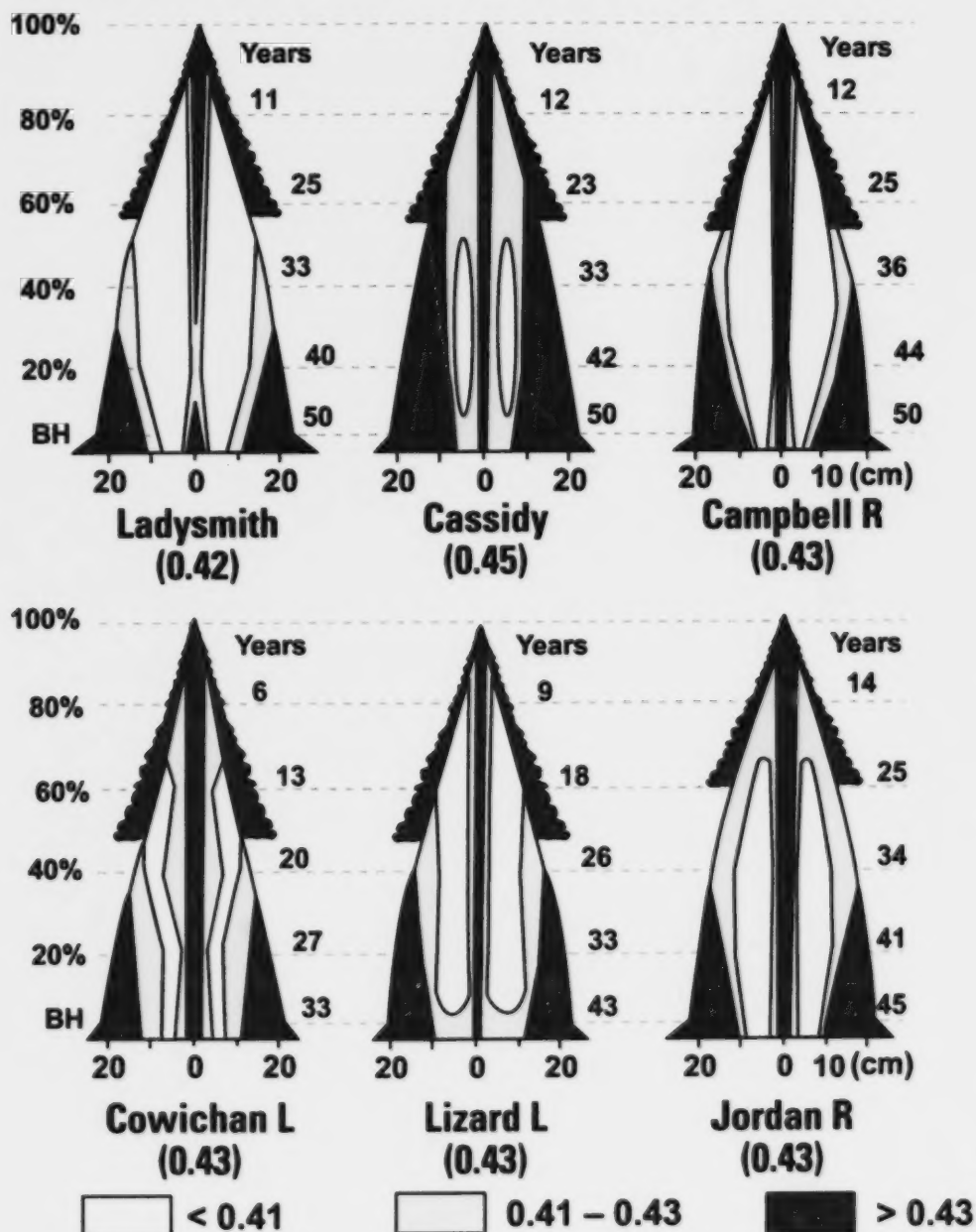
Yearly average ring density trend-lines are shown from pith-to-bark at the five sample heights (panel **c**). This is the same data that was shown in Overhead 58, except here the trend-lines are offset.

Note arbitrary density-zone demarcations at 0.41 (low), 0.41–0.43 (transitional), and 0.43 (high).

Relative density zones were mapped to show density distribution in the stemwood (panel **d**).

Relative Density Zones in Douglas-fir

Relative density



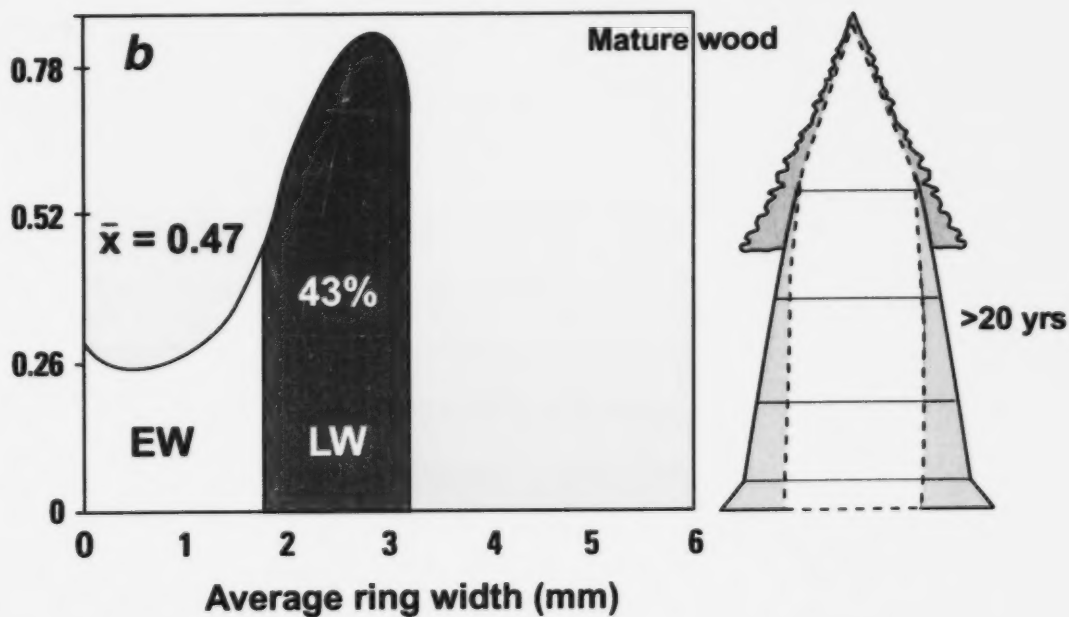
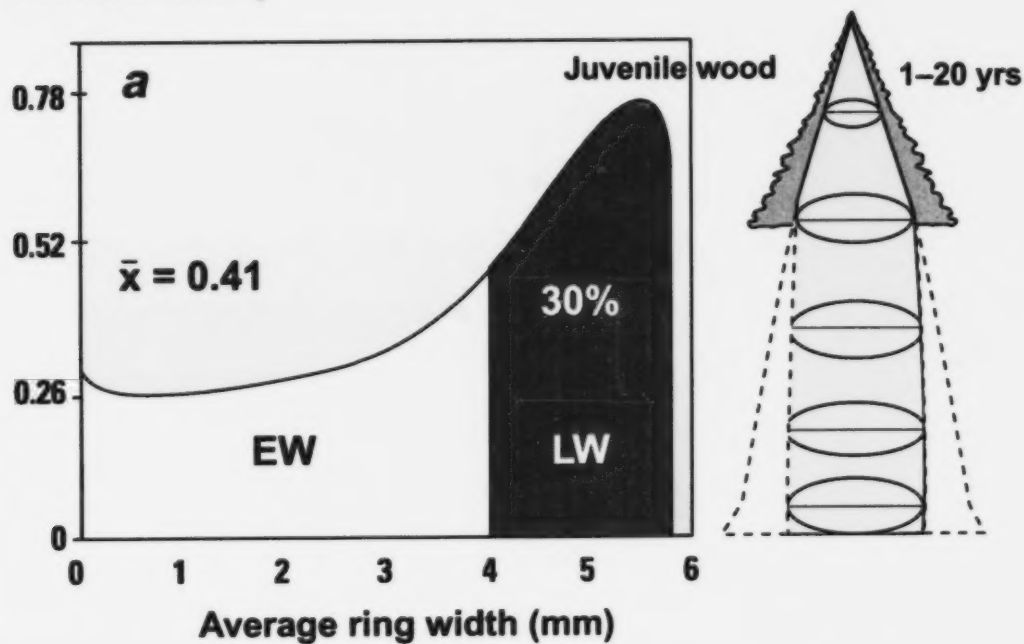
OVERHEAD 61

Low-density crown-formed wood surrounds the pith, with the exception of the "unusual" pith-associated high-density wood (definitely juvenile in character).

High density mature wood is below the live crown, surrounding the juvenile cylinder.

Juvenile/Mature Wood Ring Profiles

Relative density



OVERHEAD 62

Intra-ring density profiles show the "coarseness of grain" (number of rings per inch) through the average ring width, and wood density uniformity (homogeneity/heterogeneity) through the density range between earlywood and latewood.

This is a good time to contrast western redcedar and Douglas-fir in terms of average wood density, earlywood/latewood density range and proportion. The main difference between the two species is latewood content!

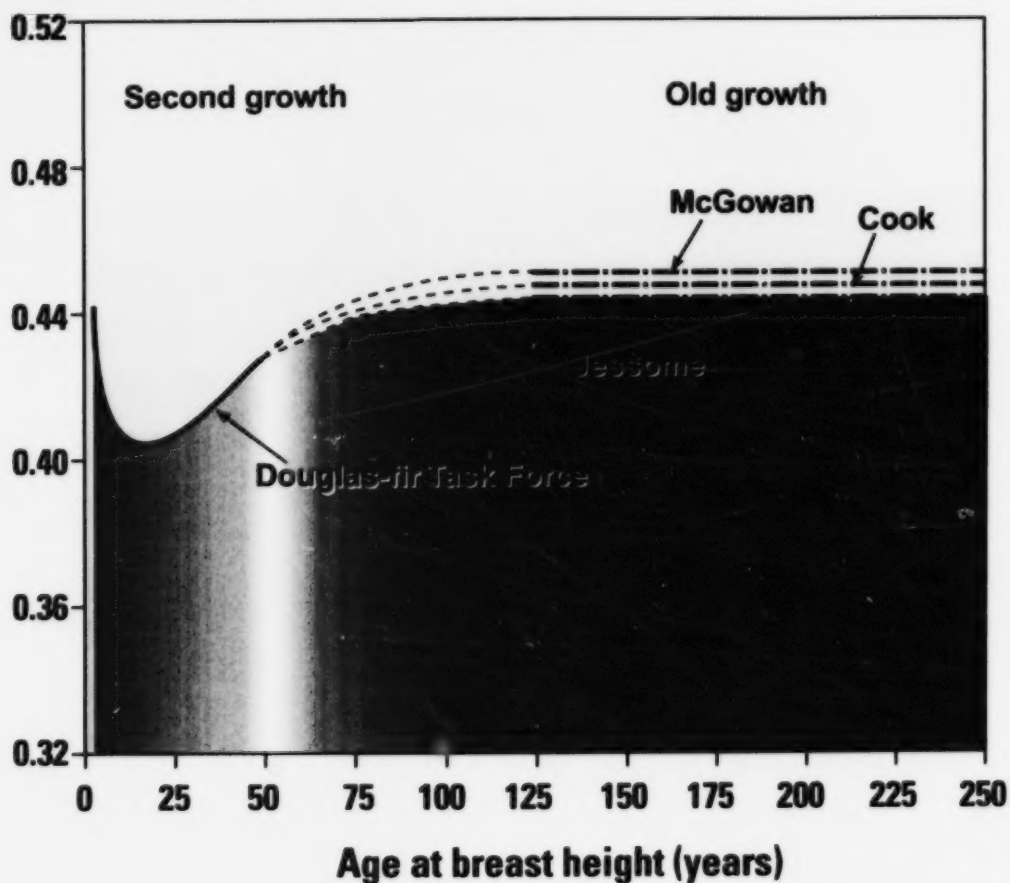
This overhead shows that on average juvenile wood annual rings are almost 6 mm wide, and they contain 30% latewood by width. Mature wood annual rings are just over 3 mm wide, and they contain 43% latewood. It is interesting that on the absolute scale the juvenile wood annual rings had 1.7 mm wide latewood bands, while the mature wood rings had about 1.3 mm wide latewood.

The range between minimum and maximum density is about the same in juvenile/mature wood. This measure is a good indicator of wood machinability.

Discuss the attributes of old-growth Douglas-fir and show some examples in terms of appearance and density.

Stem-wood Relative Density

Relative density



OVERHEAD 63

Total stemwood relative density is shown here in terms of age. As the name implies, the difference between second-growth and old-growth and second-growth is simply age.

Three different "snapshots" (wood density surveys) put old-growth average to 0.44–0.45 relative density.

This graph shows that minimum stem density was reached in these second-growth Douglas-fir trees at about age 10–15. At this age stemwood relative density is about 0.36 (not unlike spruce). By age 50 density is at 0.425, approaching the old-growth "standard" of 0.45.

Conclusions:

- ➔ These 50-year-old Douglas-fir trees, growing at 530 stems/ha, contained 50% juvenile wood and 50% mature wood.
- ➔ At all height levels, the first 20 years of growth "defaulted" to juvenile wood because of wood density, fibre length, and longitudinal shrinkage.
- ➔ Juvenile wood is not useless wood.
- ➔ Larger knots permitted in wider widths.
- ➔ Challenge: find optimum between tree size and branch size at rotation age to maximize value, keeping future trends in mind.

\$/ha/yr

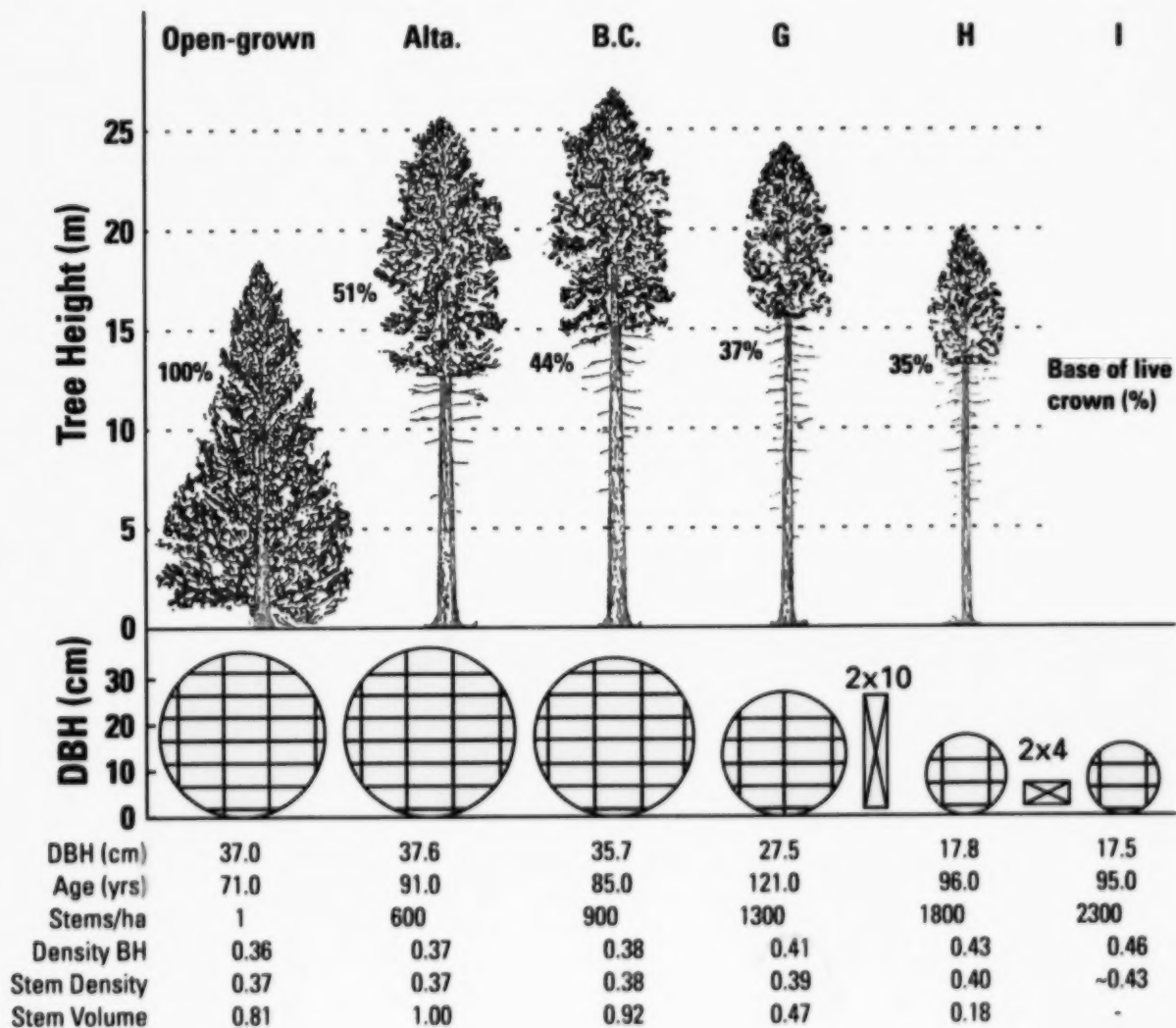
commercial forestry
has to be profitable

- Other non-woody pressures on the land base – social forestry

OVERHEAD 64

This overhead is self explanatory.

Average Dimensions of Small, Medium and Large Diameter Lodgepole Pine Task Force Trees



OVERHEAD 65

Forintek's efforts in characterizing rapidly grown second-growth tree species in western Canada started in the mid-1980s. Douglas-fir Task Force was the precedent setting study, which was followed by the Jack Pine Task Force in the east, and the Lodgepole Pine Task Force in the west.

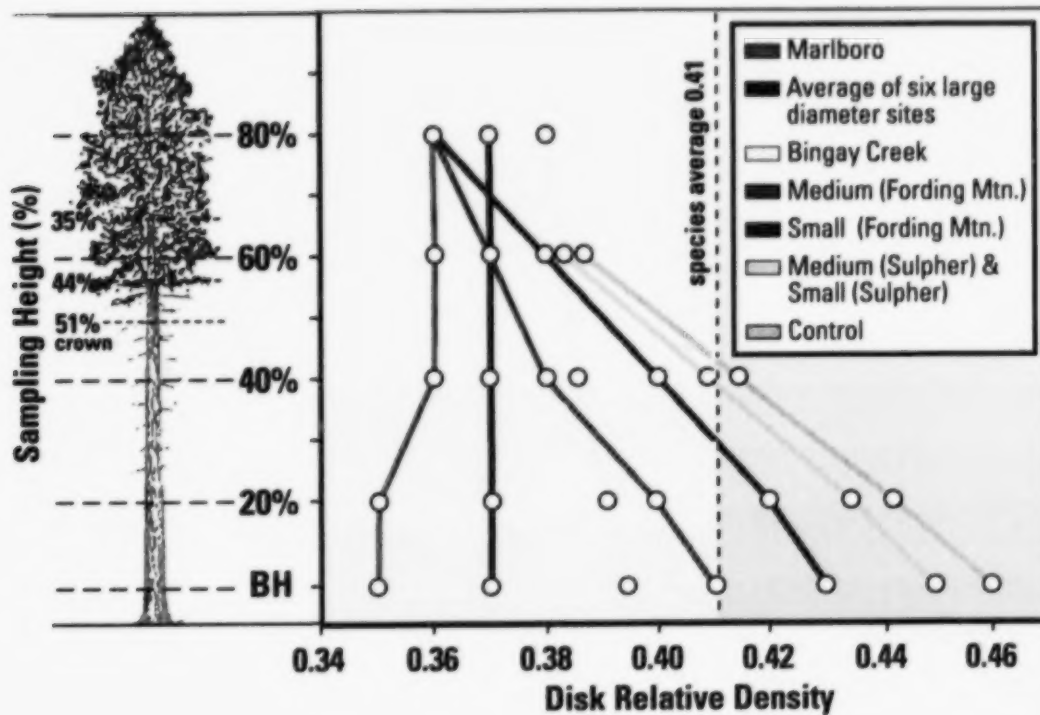
The lodgepole pine study started out with looking at the most rapidly grown stands of lodgepole pine we could find in British Columbia and Alberta. This was accomplished by identifying stands with about 750 live stems per hectare at about age 90. For those of you not familiar with natural lodgepole pine forests, 750 stems/ha is a very open and rare environment (perhaps as little as 1% of the total lpp resource). These stands were required to find lodgepole pine trees up to 40–45 cm DBH at a relatively young age of 90. The rationale was to look for potential problems associated with very rapid growth rates, in terms of product quality, like wood density, lumber strength and stiffness, and dimensional stability.

According to the BC Ministry of Forests, the average lodgepole pine harvested in BC in 1995, was 19 cm DBH, 26 m tall, and 125 years old. Therefore, our targeted tree size and age was "aggressive".

The next phase of the study included tree samples from higher stand densities and one fully open-grown tree.

This overhead shows average tree heights, diameters at BH, and the extent of the live crown. Breast-height disk density, whole stemwood density, and stemwood volume are presented as well.

Average Disk Density at Five Sampling Heights



OVERHEAD 66

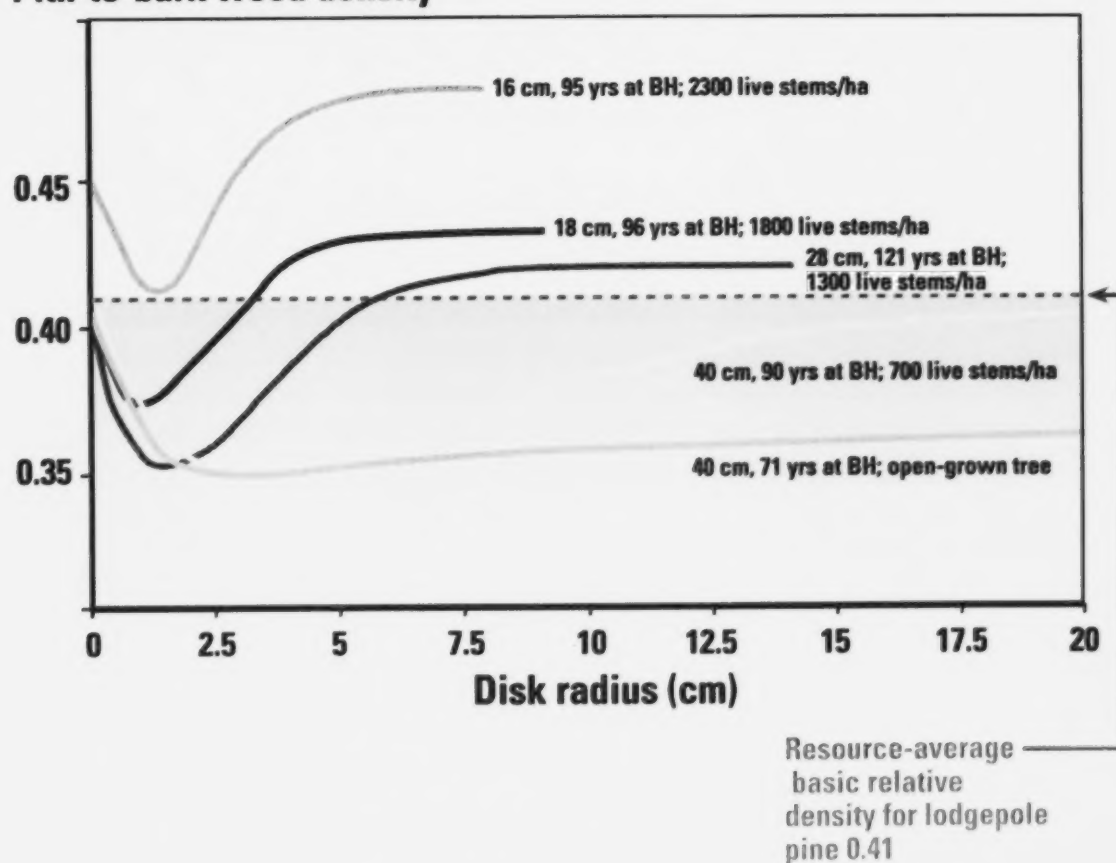
The large-diameter, relatively open-grown lodgepole pine trees have lower wood density throughout the stem, from BH to 80% tree height, than the species average of 0.41. In fact, the fully open-grown single tree had 0.37 stem density.

Smaller trees (<25 cm DBH) had higher relative density than 0.41, but always in the lower half of the stem. Maximum density was at BH, at stem base. Crown-formed wood had low relative density in all sample trees studied, from the fully open-grown tree to the 600–1800 stems/ha sample trees.

Disk density distribution suggests that log sorting, according to log diameter and log position (butt, mid, top), could be advantageous in segregating logs for specialty products. This segregation could channel high density wood for high grade MSR lumber. In secondary manufacturing (for example, furniture, flooring, etc.) the small-diameter butt logs would yield Douglas-fir-like high density wood.

Pith-to-bark Wood Density and Tree-size Trends as a Function of Stand Density

Pith-to-bark wood density



OVERHEAD 67

The period of juvenility is a function of crown recession, which is dictated by stocking/stand density. Show examples of cross-sections where one can see branch death at 13 years of age (from a high stand density of 2300 stems/ha at age 90) versus 63 years of age (from an open 700 stems/ha stand).

Note the lodgepole pine resource average basic relative density of 0.41. These last two overheads, and the two coming up, should be examined at great lengths by silviculturists and by individuals who are responsible with setting product objectives!

OVERHEAD 67A

Yearly ring density trends from pith-to-bark, at five sampling heights.

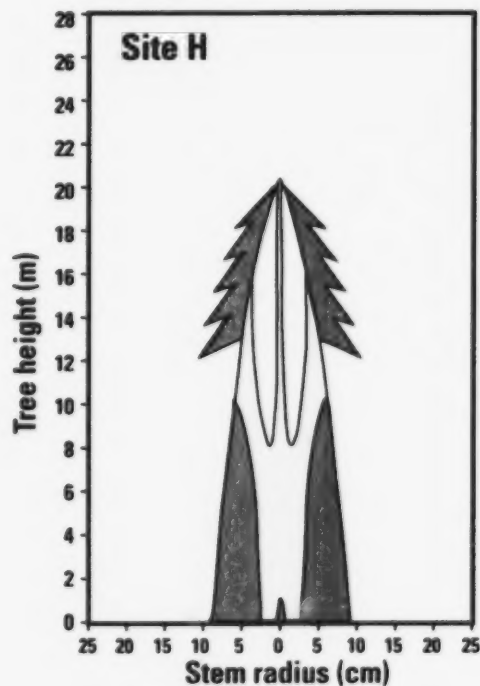
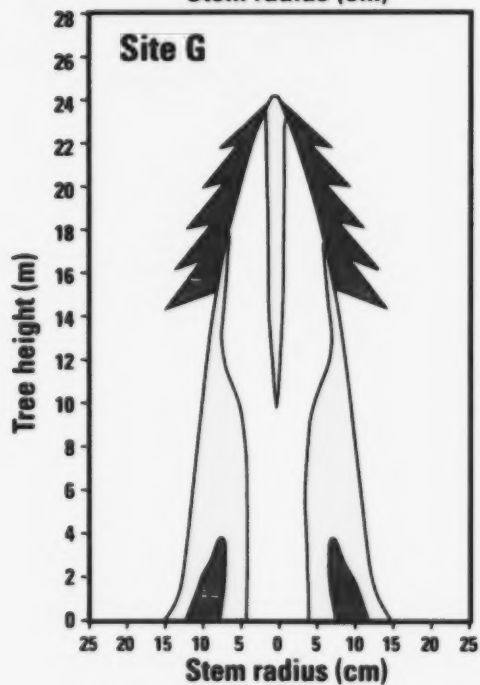
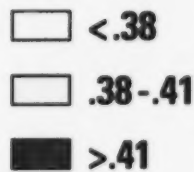
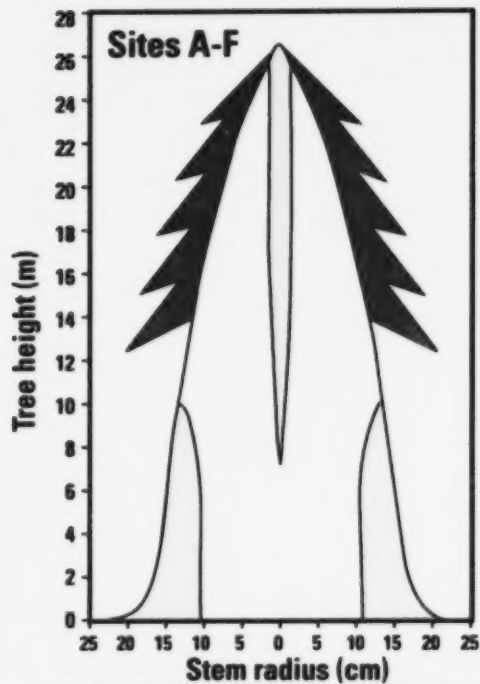
Note the "target" at 0.41, and the weighted average stem densities at 0.37, 0.39, and 0.40.

Note the dramatic upswing in density as we shift from the large-diameter trees to the medium-, and small-diameter trees.

Note how the period of juvenility "shrinks" at BH from about 35 years to 15 years from medium to small trees, respectively.



Second Growth Lodgepole Pine Density Distribution

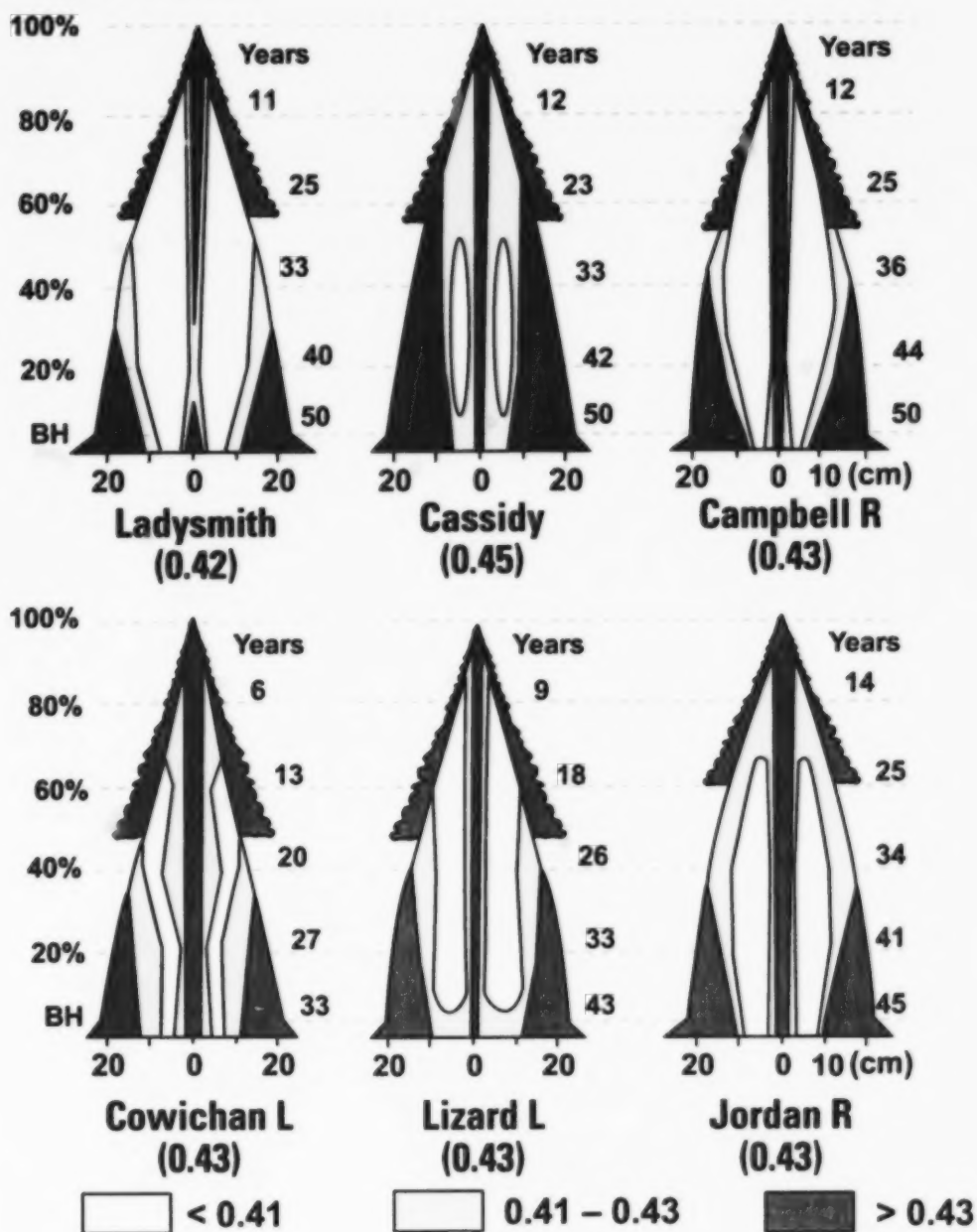


OVERHEAD 68

These stem profiles and density distributions were constructed with the help of trend-lines shown in overhead 71. Log merchandising and product potential for MSR lumber are points to ponder.

Relative Density Zones in Douglas-fir

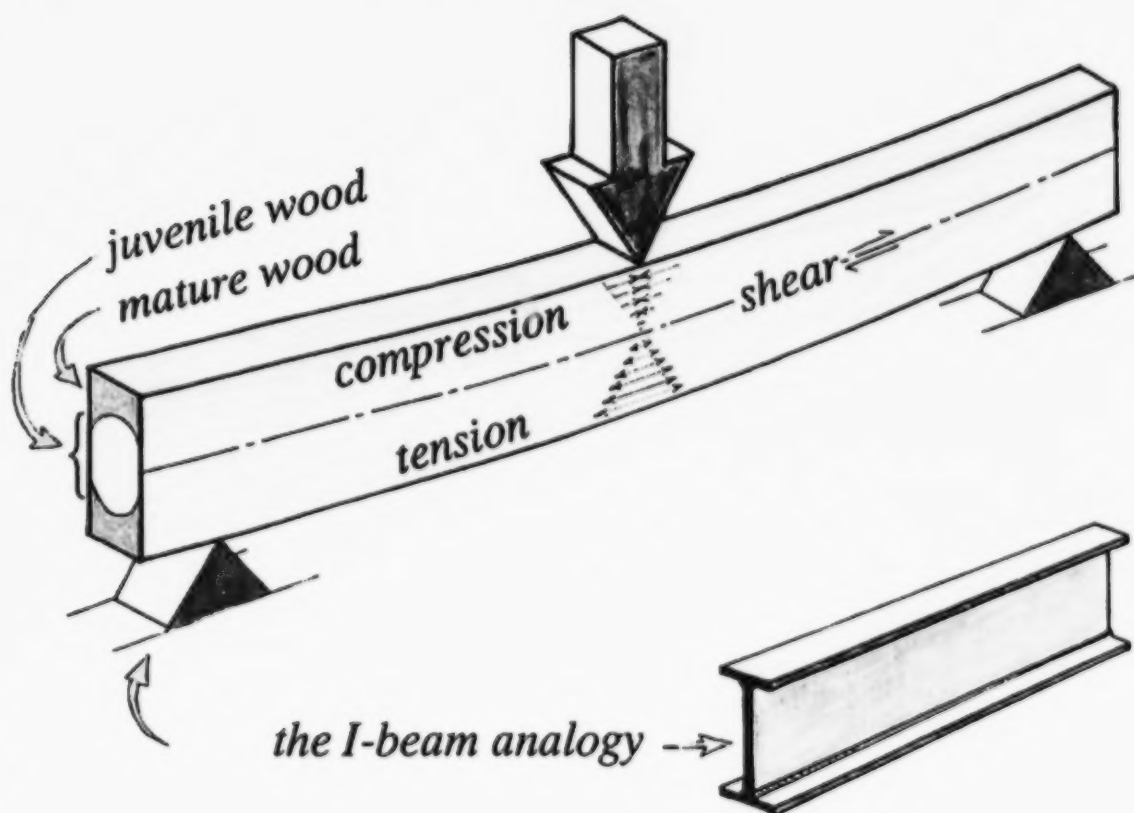
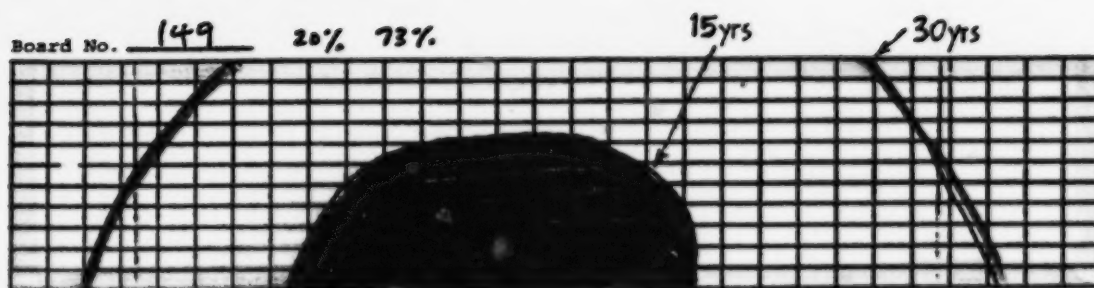
Relative density



OVERHEAD 69

Rapid increase in lumber recovery factor (fbm/m³) is evident from 150 to 250 fbm, from 10 to 20 cm top log diameter. The recovery factor levels off at 30 cm diameter.

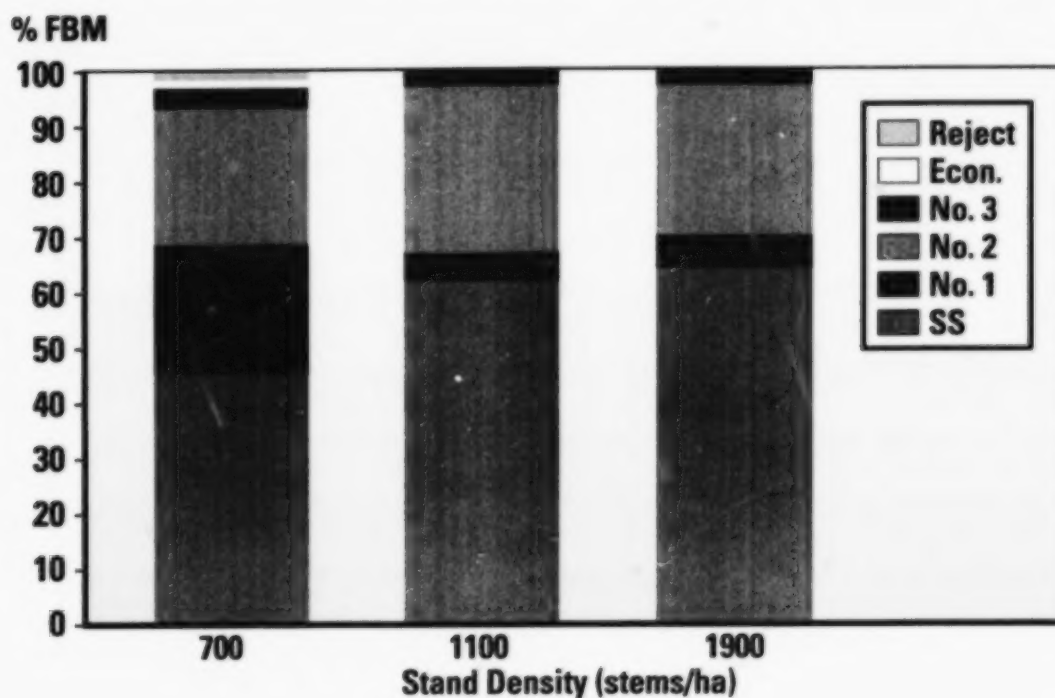
Need large logs to produce wider widths! (e.g., need minimum 25–30 cm top-diameter logs to produce 2 × 10 lumber).



OVERHEAD 70

Self explanatory; for additional information please read page 14 of SP No. 34.

Structural Lumber Yields by Visual Grading

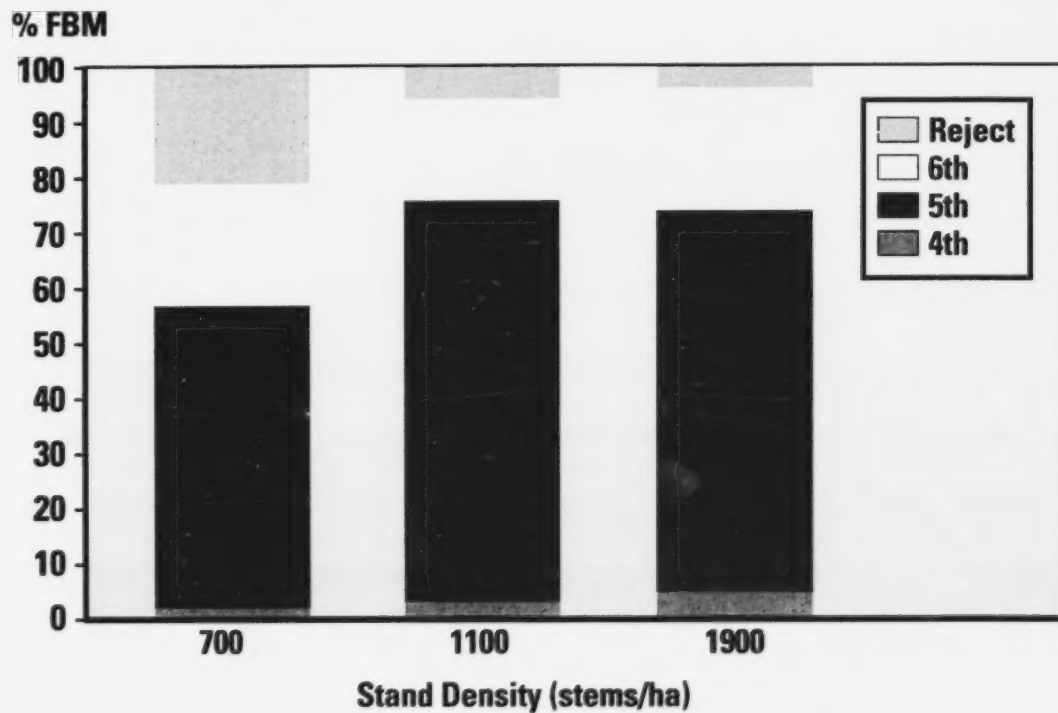


OVERHEAD 71

Even at 700 stems per hectare there is 94% No. 2 and better lumber yield, however, Select Structural yield is up to 65% at the 1100 and 1900 stems/ha (from the 45% at 700 stems/ha).

The first exercise in this type of grade yield and value study is to come up with the weighted average value; that is, combine the value (\$/fbm of SS, No. 1, No. 2, etc.) with lumber yields (lumber recovery factor times m^3 of logs from the three stands). There are a number of potential pitfalls. First, what lumber price do we use in our calculations? – in our study we used 10 year average lumber prices (to accommodate periodic fluctuations). Second, it is difficult to get prices for Select Structural, No. 1, and No. 2 separately; usually, prices are quoted as “Standard & Better”.

Door, Window and Furniture-Grade Lumber Yields by Visual Grading



OVERHEAD 72

The top grade is "4th", followed by "5th" and "6th". The 1100 and 1900 stems/ha trees produced very similar grade yields (~75% 4th and 5th), while the 700 stems/ha trees yielded ~55% 4th and 5th.

Refer to the maximum knot-size allowances wooden prop (live and dead maximum diameters are shown).

MSR Summary

Uses of MSR Lumber

- ➔ Primarily for roof trusses, I-joists, laminating stock for glulam
- ➔ Parallel chord floor trusses – new market (ease of handling, longer spans, ready openings for wiring, plumbing and ductwork)

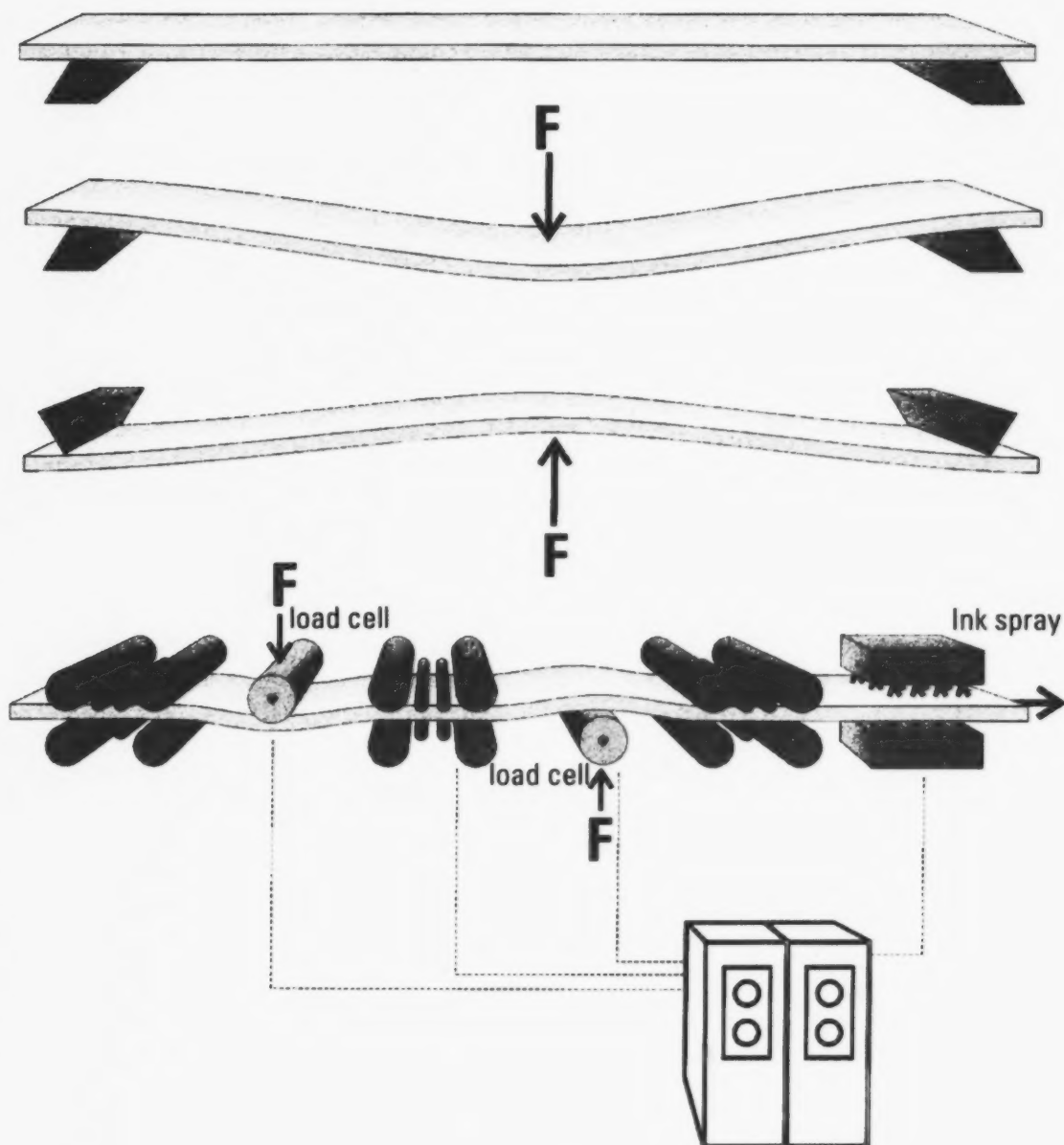
Advantages of MSR Lumber

- better consistency because of E rating (more uniform "links")
 - quality control in the plant – none with visually graded
 - lumber can be cut from small logs (no need for very wide widths)
 - reduced variability = reliability and exactness
 - reduced waste (2% vs 10%)
 - uniformity across "species boundaries" (fewer grades)
 - **Profit** (marketability)
-

OVERHEAD 73

Machine Stress Rated (MSR) lumber is going to be more and more common in the future in structural applications. There is a global "push" by structural engineers for MSR lumber grades because of the greater reliability in terms of design and performance (when compared with visual grades). In spite of the great potential for MSR lumber, in 1996 little more than 5% of all lumber cut in North America was MSR'd.

MSR Grading System



OVERHEAD 74

MSR grades are determined in the sawmill at production speeds, about 1000 feet/minute. This schematic shows the concepts and the main elements. Each piece of lumber is "flexed" from both top and bottom (not unlike the instructor standing in the middle of an 8' 2 x 4, supported on the two ends on chairs). Although the piece of lumber is loaded on the wide face, the strength and stiffness result is equally valid for the narrow face as well. Computer assisted photocells determine the beginning and the end of each stick of lumber.

(It might be a good time to quiz students if they know the difference between strength and stiffness. Which one of the two measurements is the more important one?)

It is very important to put in perspective MSR lumber production, not only in BC, but elsewhere as well. Experts tell me that if we were to take atypical BC interior S-P-F mill that pulls MSR lumber, the following is the average yield: About 80% of the lumber gets a spray mark. In other words, 80% of the pieces going through the machine are stiff-enough. However, only about one half of these pieces will pass the visual inspection that looks for large edge knots and excessive wane. Therefore, just because a sawmill cuts MSR lumber not all lumber will pass the machine and visual override; typically, only 40% gets the MSR stamp. The next challenge is, what are we to do with 60% of the lumber that did not make it?

Strength of wood

is the resistance to forces deforming it.

- ➔ There are still other things besides relative density that affect the strength of wood.
 - ➔ These include knots, slope of grain, compression wood, the relative amounts of earlywood and latewood, moisture content, temperature (above 65°C), and fibril angle (the part of the tree, near the pith, or farther out from which the piece was cut).
 - ➔ A few basic terms in wood mechanics:
 - force:** push, pull and shear
 - stress:** force per unit area (psi)
 - strain:** unit deformation
 - stiffness** (elasticity): stress/strain
 - creep:** continuously stressed in bending, "flow", "sag"
 - fatigue:** loss in wood property due to repeated force application (bending back and forth, 1/3 max. stress, 30,000,000 times)
-

OVERHEAD 75

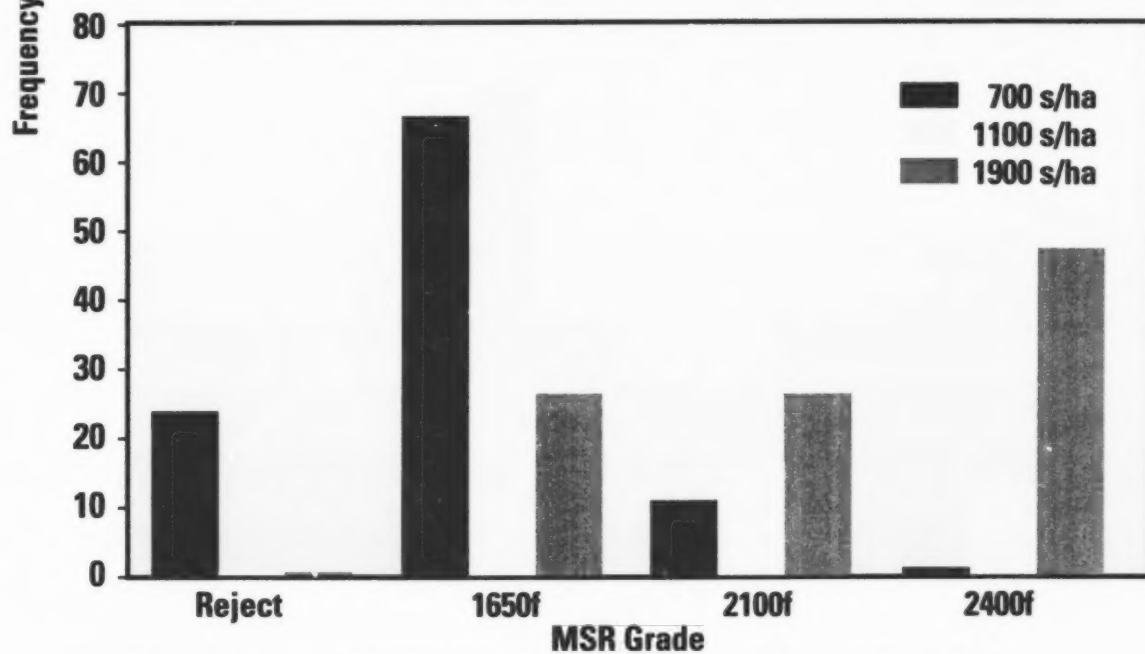
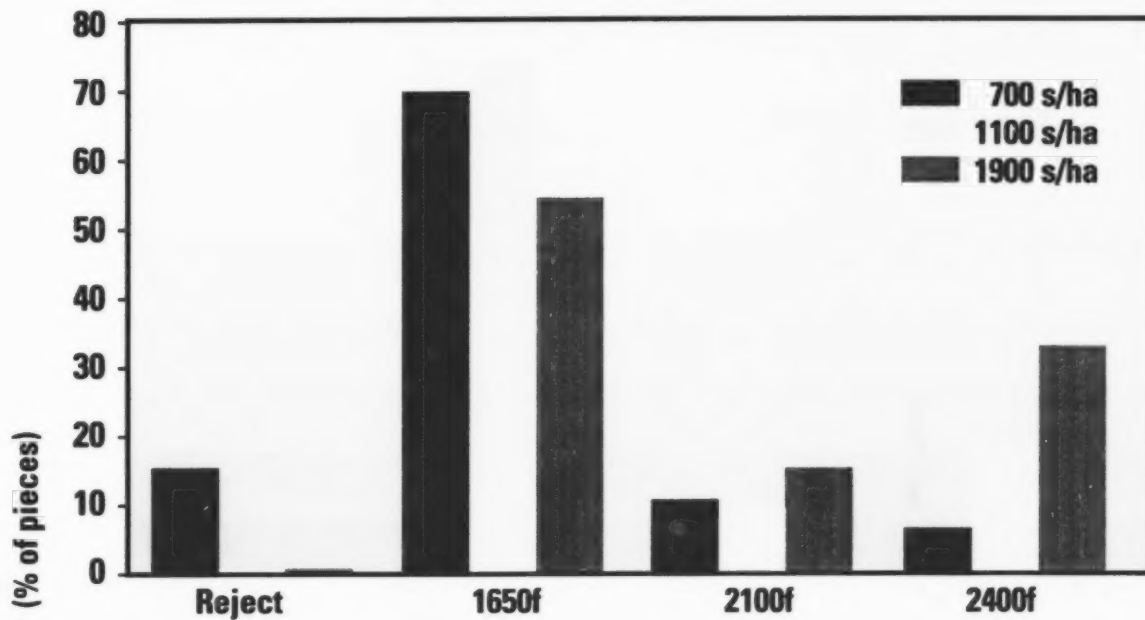
One reason that wood is often neglected by architect and engineers for many construction applications is its great variability in strength properties within visual grades. For this reason there is an international movement that insists on MSR structural lumber grades.

Machine stress rating consists of a collection of machinery, methods, and rules which make use of a nondestructive measurement of certain physical properties to classify lumber for use in structures, where their performance must meet minimum standards.

To get in the right frame of mind, we will review some of the basic terms that describe the strength properties of wood. We will use the "popular" meanings to avoid confusion.

Machine-stress rated lumber yields

Distribution of MSR Grades for 2x4's by Stand Density



Distribution of MSR Grades for 2x6's by Stand Density

OVERHEAD 76

Machine Stress Rated Lumber Yields are discussed in great detail in Forintek's Special Publication No. Sp-35 (p. 46-53).

Visual **"over-ride"** is used to eliminate potential problem pieces that could include large edge knots, excessive wane (**truss manufacturing can not use waney lumber because the metal-connecting plate staples do not stick too well to air!**), decay, etc.

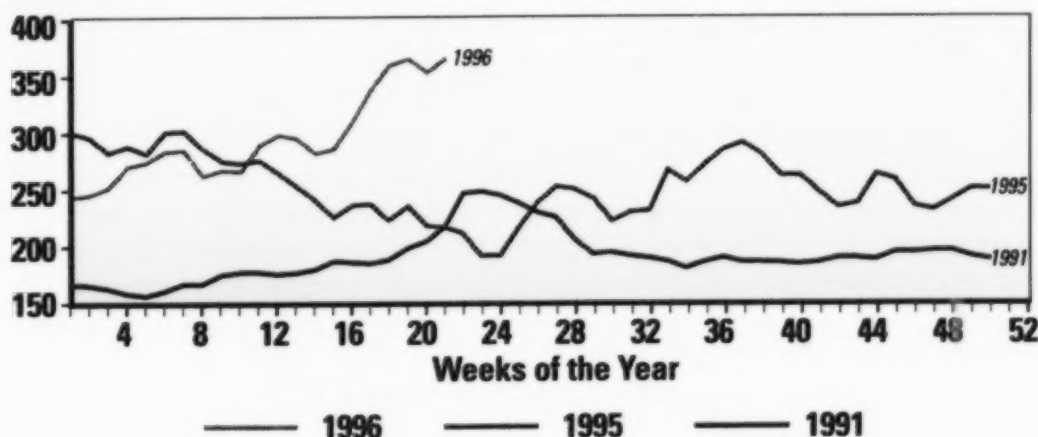
Refer to the lumber display, showing different grades, including down-graded pieces (with the blue or red paint streak).

OVERHEAD 76A

This graph shows the total tensile loads allowed by present design rules for different grades and dimensions. Note how the visual grades suffer, especially with the wider widths, when compared with MSR lumber.

Western SPF KD Std&Btr Random Lengths – 2x4

US Funds –
FOB Mill



As reported by Madison's Canadian Lumber Reporter – May 24, 1996

MSR Lumber—Kiln Dried—8'/20'

2x4 SPF			2x6 SPF	
1650f	\$490	{450}	\$440	{400}
1800f	495	{455}	n/a	n/a
2100f	495	{460}	465	{425}
2400f	520	{480}	480	{440}

*Prices are in U.S. funds, F.O.B. Chicago
Prices in () are f.o.b. Vancouver

As reported by Madison's Canadian Lumber Reporter

OVERHEAD 77

The author keeps track of Canadian lumber prices through reading Madison's Canadian Lumber Reporter.

Showing the top half of this overhead gives a good example of the volatility of lumber prices over a two-and-a-half-year-period. The price shown is for random length S-P-F 2×4 , Standard & Better grade. We can see a selling-price of about \$350 (USA) in the 20th week of 1996. This price is being shown as a reference point in terms of MSR lumber price premiums (reveal the bottom half of the overhead).

We can see about \$100–150 premium for MSR lumber. Herein lies the incentive for Mechanical Stress Rating. Examine and discuss price differences between different strength classes, and between 2×4 and 2×6 . Why would a sawmill manager want to cut 2×6 dimension when 2×4 is selling at a higher price/thousand?

OVERHEAD 77A

Data shown here is based on actual laboratory measurements of 1 371 pieces of 2 × 4 lumber. Note that the high- strength pieces (2400f-2.0E) have high basic-relative-density.

Note the lodgepole pine species average density of 0.41 correspond to 1800f.

Superimpose our large-diameter and open-grown tree average densities; 0.38 and 0.36, respectively.

This graph demonstrates that low-density woods, such as subalpine fir (0.33), will yield little MSR lumber.

Re-emphasize an earlier point— a typical interior S-P-F mill that makes MSR lumber will have the following “batting average”; although 80% of the lumber will get sprayed, only one half will pass the visual check. Therefore, 40% of the lumber will receive the proud MSR stamp, however what will happen to the 60% that did not make the grade? Answering this question will be a challenge to mills with low-density wood, who will not be lobbying for MSR standardization— they will be more than happy with the visual grades.

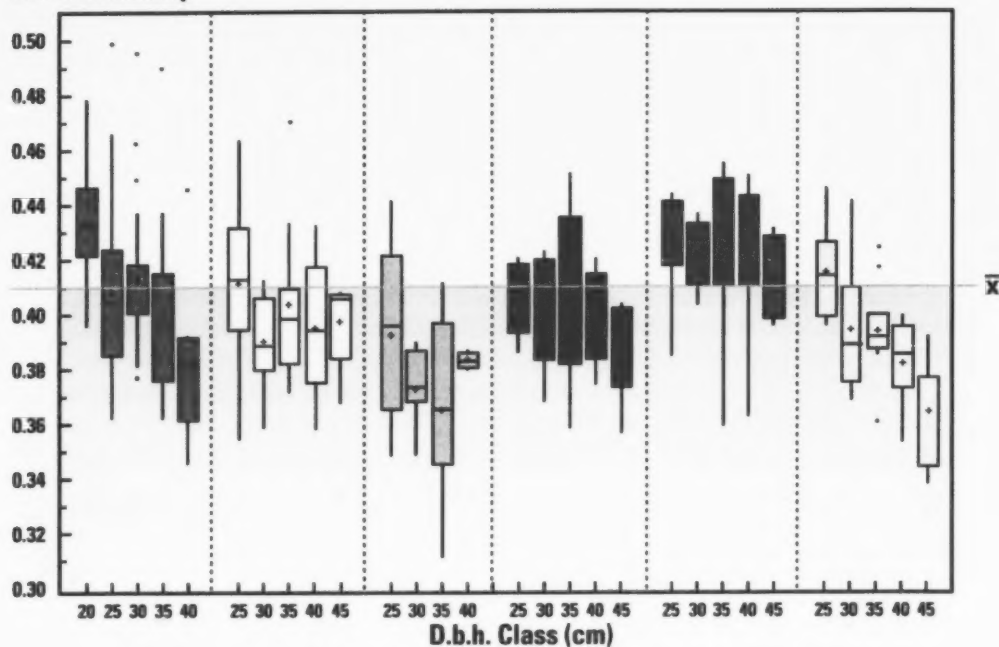


OVERHEAD 77B

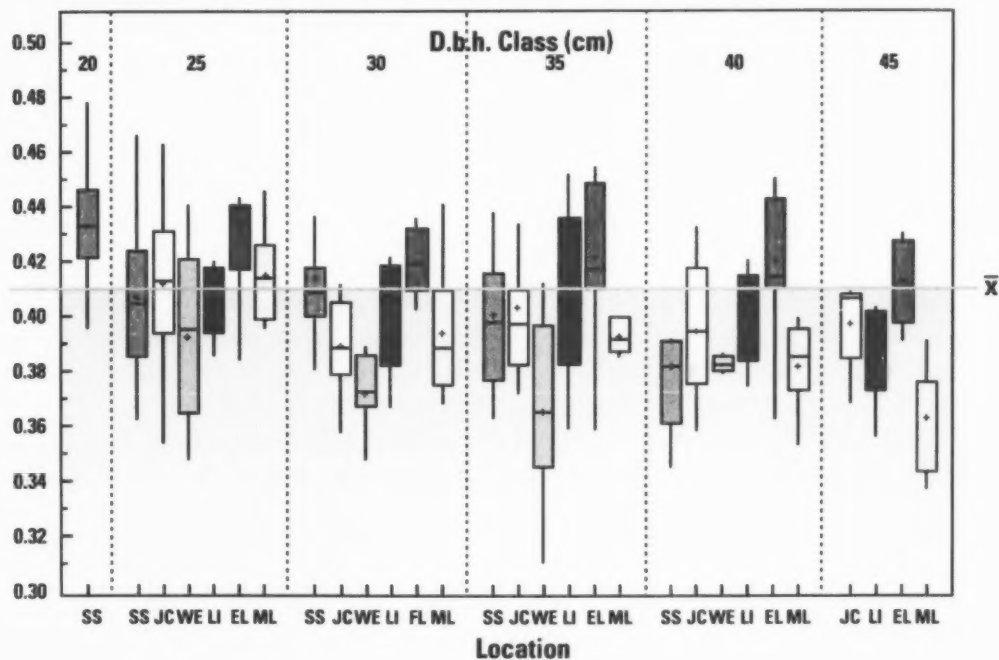
Look this table up in SP No. 35 and read background information, and necessary qualifications.

The main point here is that the middle of the road seems the best, using today's product prices and expectations (good-grade lumber is more valuable): at 700 stems/ha the problem is with quality, in terms of visual SS top grade, and MSR yields from the big "pumpkins"; at 1900 stems/ha sawlog volumes were lower.

Breast Height Relative Density



Sulphur Springs (MS) = SS Wells (ESSF) = WE Elbow Lake (ICH) = EL
 Jamieson Creek (MS) = JC Likely (IDF) = LI Modeste Lake (SBS) = ML



OVERHEADS 78

This overhead should be shown first with the bottom-half covered up. Forintek's special publication No. SP- 36 should be read for background information, particularly the "Wood Density" heading on page 13.

The main point of the **Regional Comparisons of Wood Density and Knot Size in Low Stand Density Lodgepole Pine** report was that it confirmed the study results of the Lodgepole Pine Task Force, carried out in the SE corner of BC. In other words, the results are valid throughout the province.

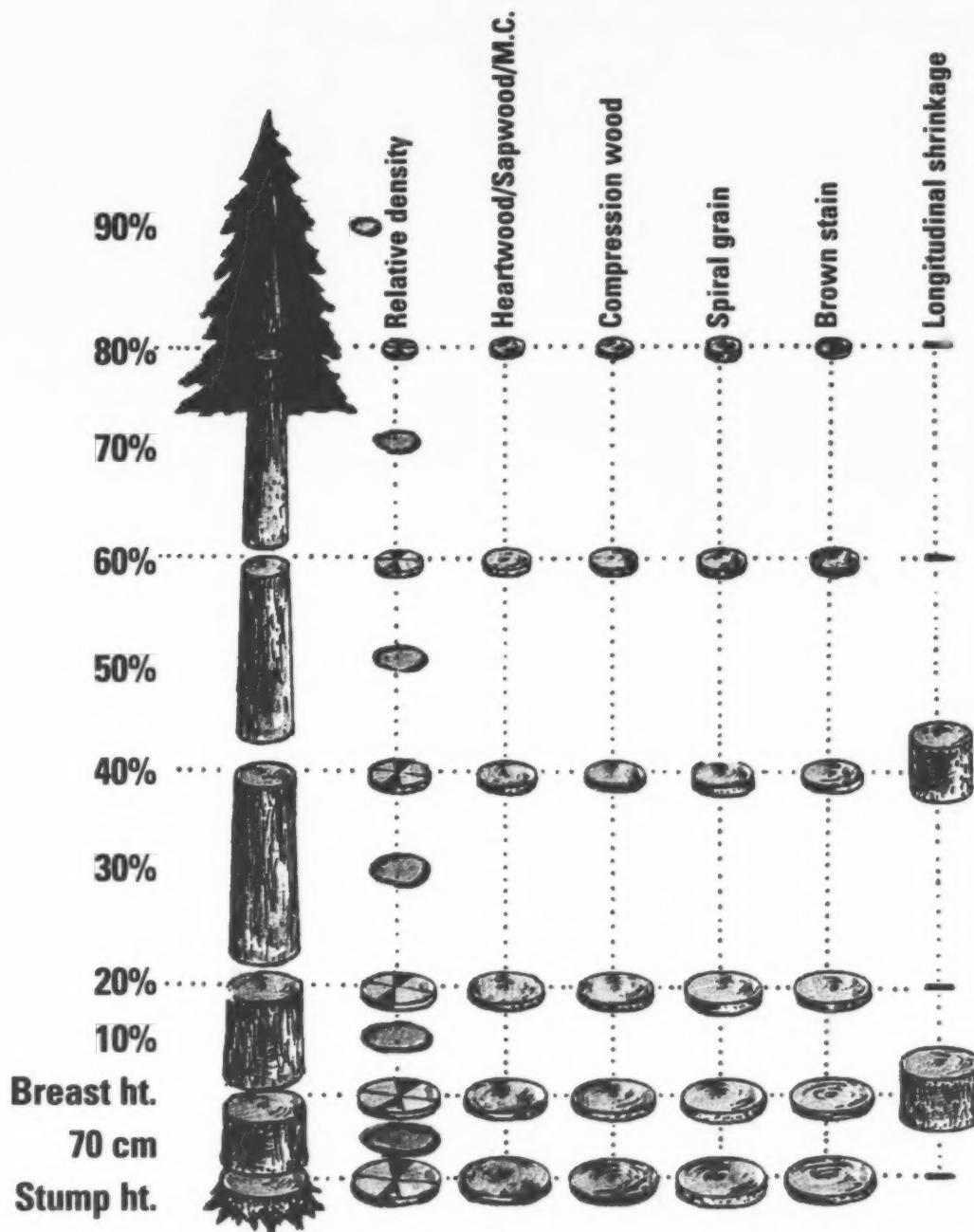
One pleasant surprise was the Interior Cedar Hemlock (ICH) biogeoclimatic zone— here even the >30 cm DBH trees had equal or higher density than the target 0.41. Most likely explanation is soil moisture availability during the summer months (July and August) when the latewood is laid down, and the tree can keep-on growing (instead of suffering from soil-moisture-deficit). Further work in the ICH zone will determine if the higher wood density and smaller branch sizes resulted from the slow 30 year growth rate (a stand effect), or from specific zonal growing conditions (as hypothesized above).



OVERHEAD 78A

Map of sampling locations for western hemlock basic wood properties study. Ninety year old trees were sampled at five locations, from 450 to 1000 stems/ha.

Thirty-nine year old trees from Haney provided a controlled sample set for examining stocking density effects on stemwood density at 3×3 , 9×9 , and 12×12 foot spacings.



Sampling plan for basic wood properties characterization of second-growth western hemlock.

OVERHEAD 79

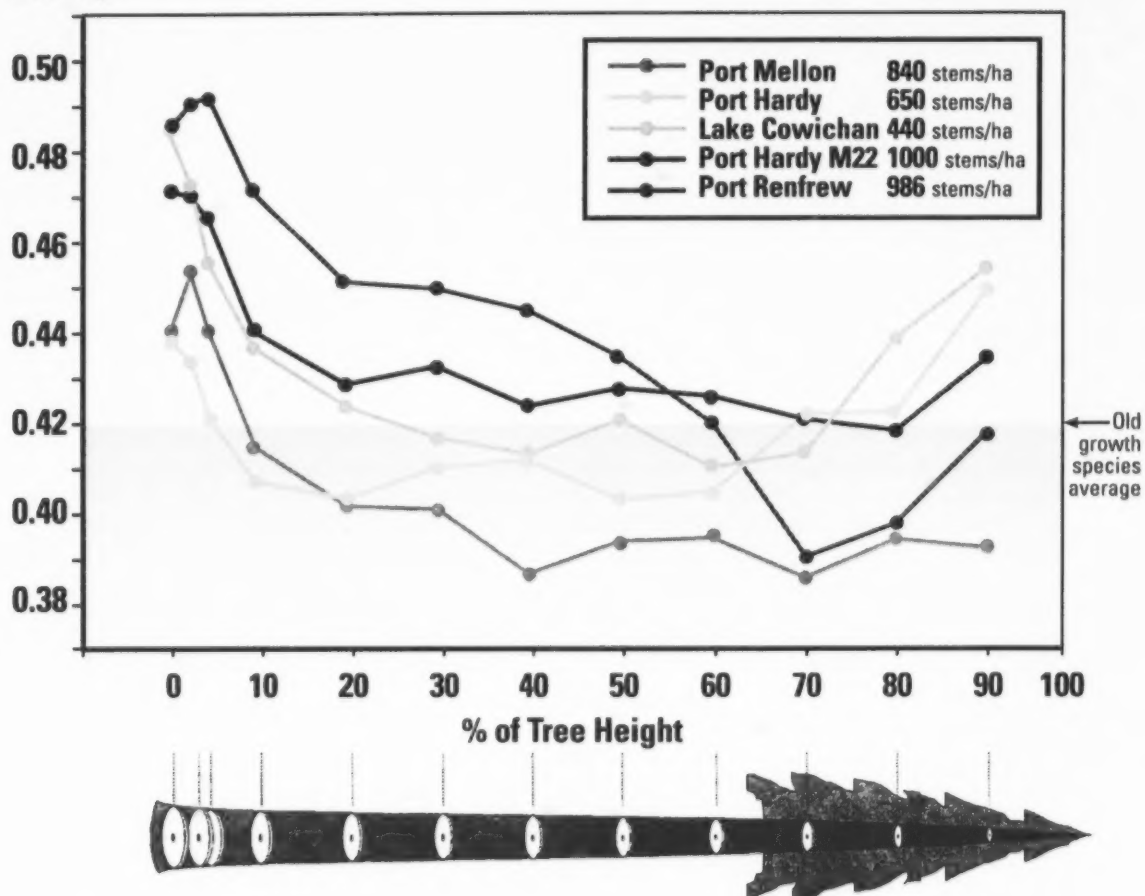
Sampling plan for basic wood properties characterization of 90 year old second-growth western hemlock. To accommodate the BC Ministry of Forests Research Branch needs, we increased the sampling intensity for yearly pith-to-bark relative density measurements from five height levels (@ BH, 20, 40, 60, and 80%) to 12, adding the stump, 70 cm, 10, 30, 50, 70, and 90% height disks. This additional "resolution" was required for modelling tree growth for TASS and other applications.

Outline the need for the basics in terms of the six variables, and relate to old-growth "standards" whenever possible (e.g., Strength/stiffness, permeability, dimensional stability, and appearance).

Second-growth Western Hemlock

Disk Densities at 12 Heights for Five Sites

Average Relative
Density

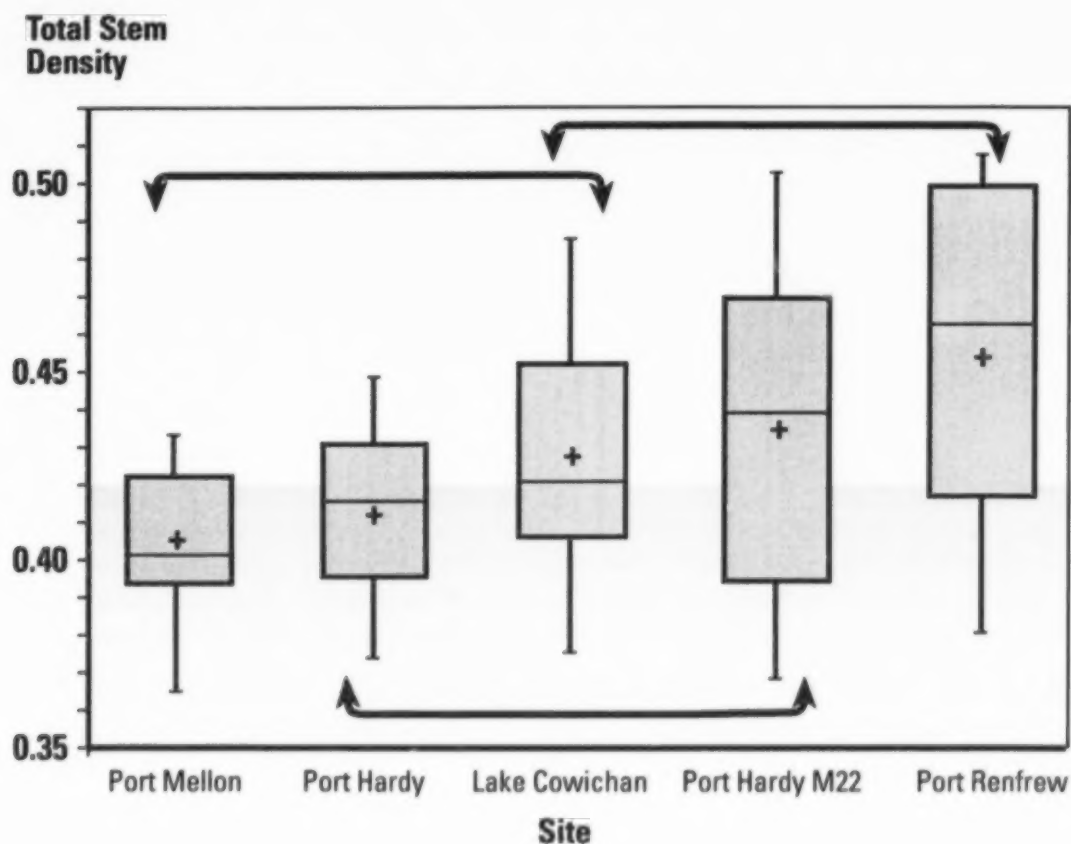


OVERHEAD 80

Disk densities, in relation to the 0.42 old-growth reference standard, show that these 90 year old western hemlock trees are producing "good wood". In fact, we can state that the bottom 10% of the stem, on average, is Douglas-fir-like in terms of relative density. The 50 year old Douglas-fir Task force trees had a BH disk density of 0.46, while at 20, 40, 60, and 80% relative density of disks were 0.44, 0.41, 0.41, and 0.42, respectively (overhead 63 b). Equally intriguing is the wide diversity in relative density of the top wood, at 70, 80, and 90% height levels.

The Port Mellon sample, at 850 stems/ha, seems the "odd-ball" in this comparison. More on this later, when we describe the "Haney trees".

Second Growth Hemlock – Total Stemwood Density Distribution



OVERHEAD 81

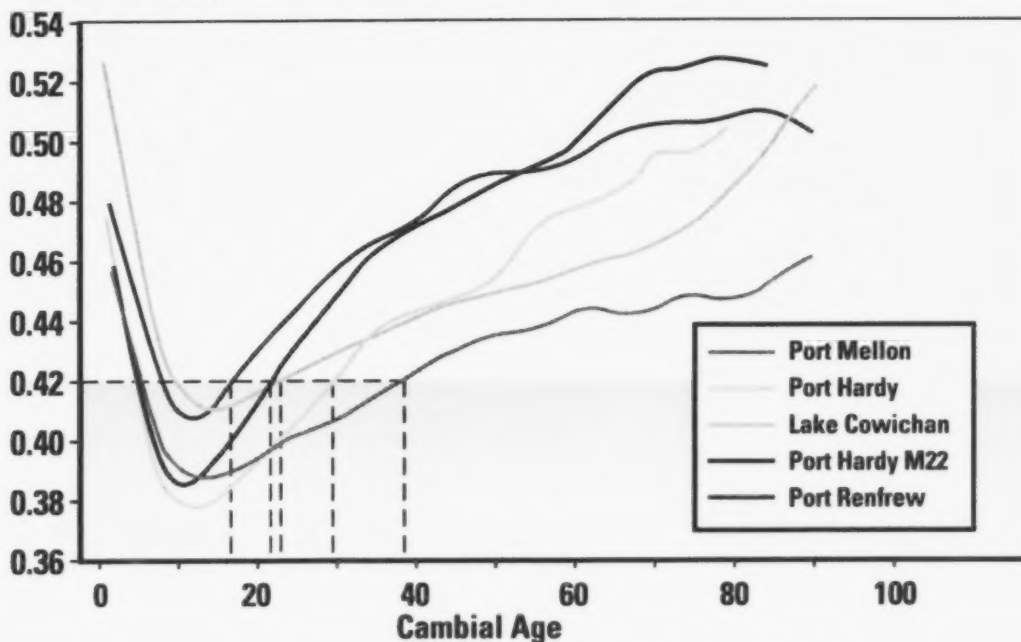
These box plots show not only the site means (“+”), but also the distribution of the total stemwood density data at each location. The top and bottom edges of the boxes indicate the 75th and 25th percentiles of the sample, respectively. The horizontal lines within the boxes show the sample median, and the vertical lines extending from the boxes indicate the full range of the data. The horizontal brackets show site groupings where no statistically significant differences were found (at 0.05 level).

These results show that there is lot of opportunity for exploiting high-density stems for specialty target products. These include MSR lumber and furniture wood.

It is reassuring to the resource manager that even at 440 and 650 live-stems/ha, at age 90, the old-growth reference value of 0.42 was equalled (0.41 and 0.43, respectively).

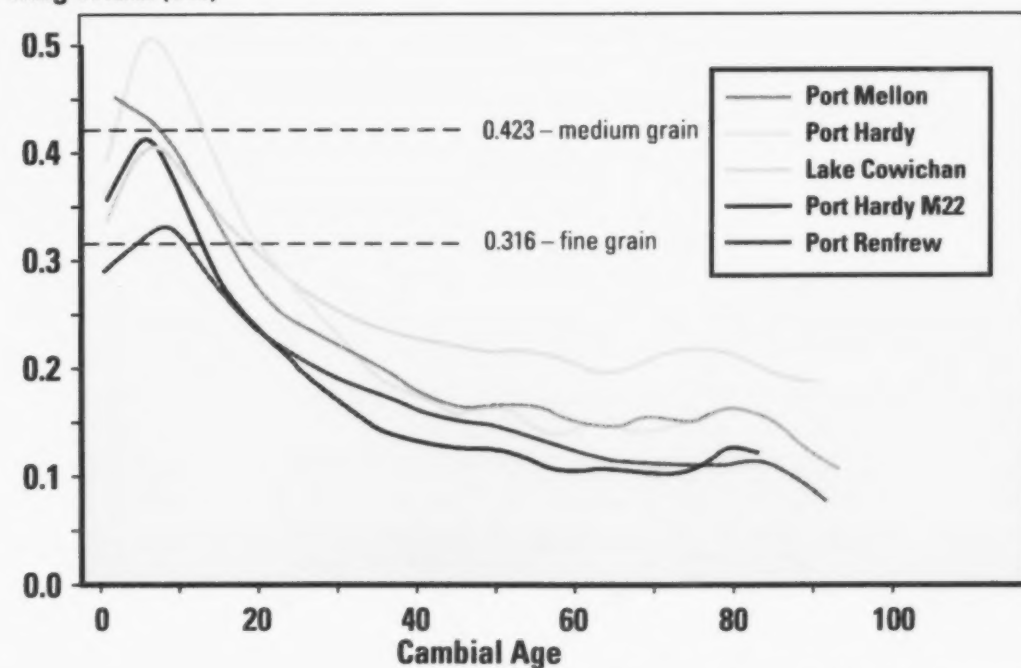
Average
Relative Density

Pith-to-Bark Density Profiles



Ring Width (cm)

Pith-to-Bark Ring Width Profiles



OVERHEAD 82

(Cover the bottom half of this overhead to facilitate the discussion about wood density trends)

Pith-to-bark yearly ring density trend-lines show a rapidly declining trend from the pith-ring (age 1) to age 10. This comparatively high density wood is juvenile wood (as juvenile as it can get, in fact). The low-point in density (about 0.40) is reached between age 10–15, about 3–7 cm from the pith. These trend-lines were created by summarizing all rings from each of the 12 sampling heights.

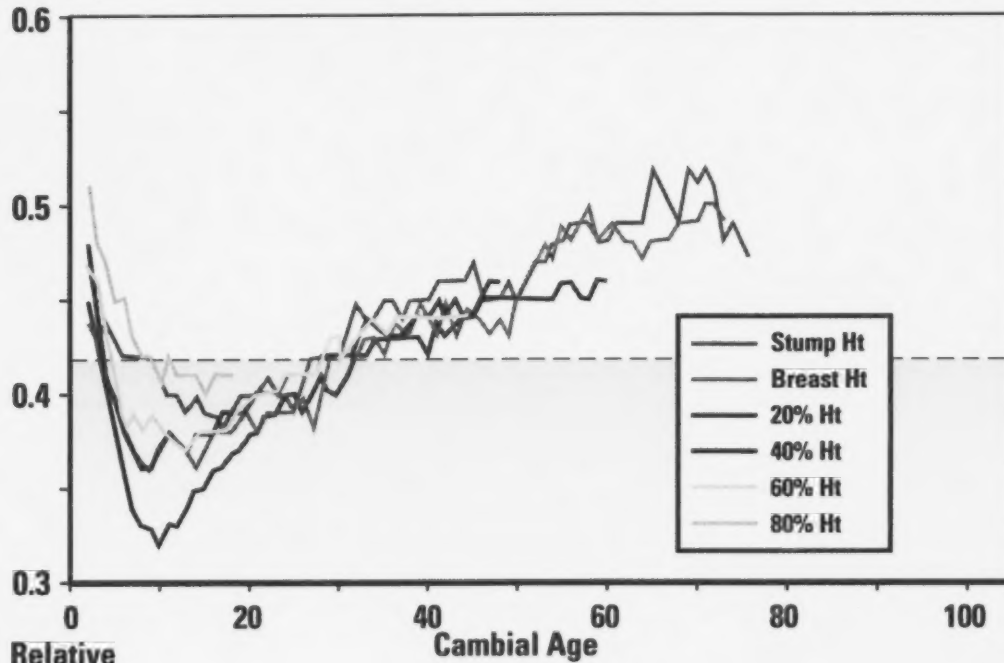
(Show bottom half of overhead for ring width trends)

Maximum ring width was reached at all five sites between age 5–10. This was followed by rapid decline in ring width to about age 30. From here on a very gradual decline is evident.

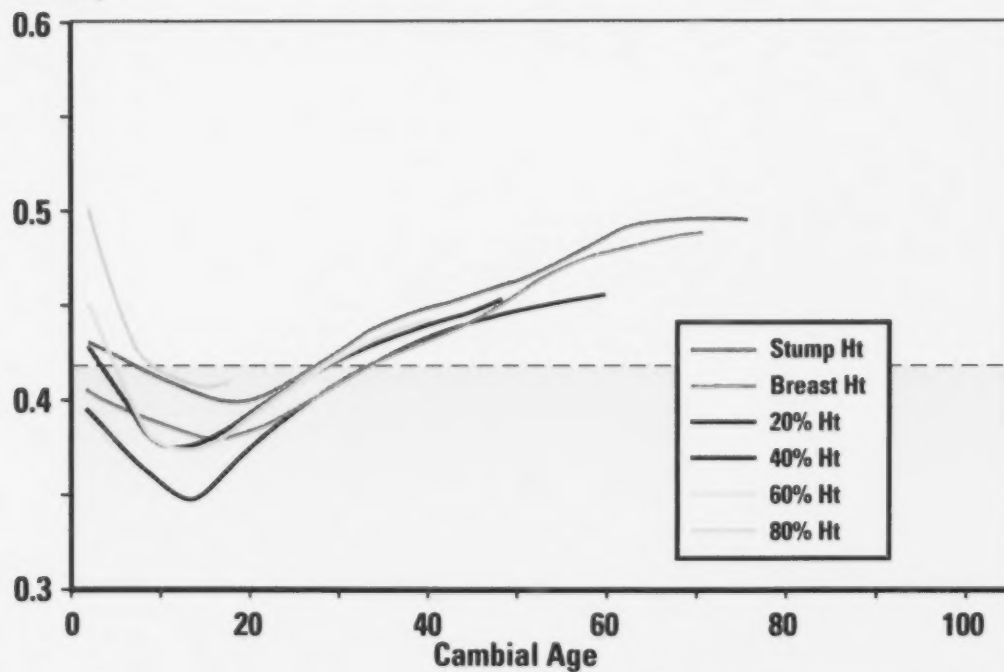
The practical significance of ring width can be related to current NLGA grading rules; top grade in vertical grain door stock requires at least 8 rings/inch, or 3.16 mm wide rings. The next grade requires <4.23 mm in ring width (6 rings per inch).

Western Hemlock Port Hardy Summary of 13 Trees

Relative
Density



Relative
Density



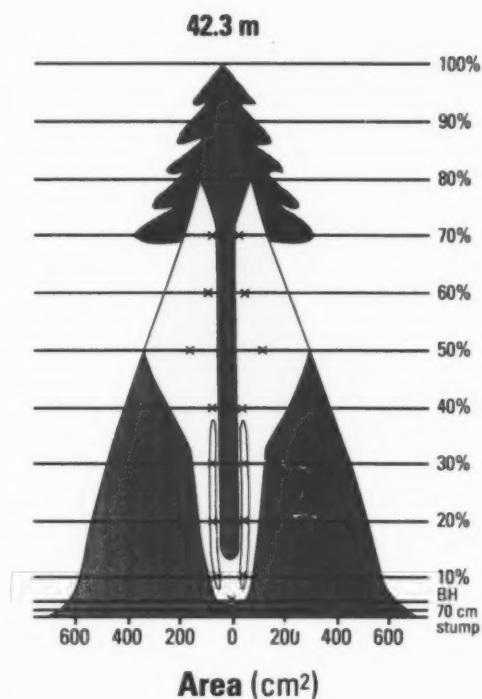
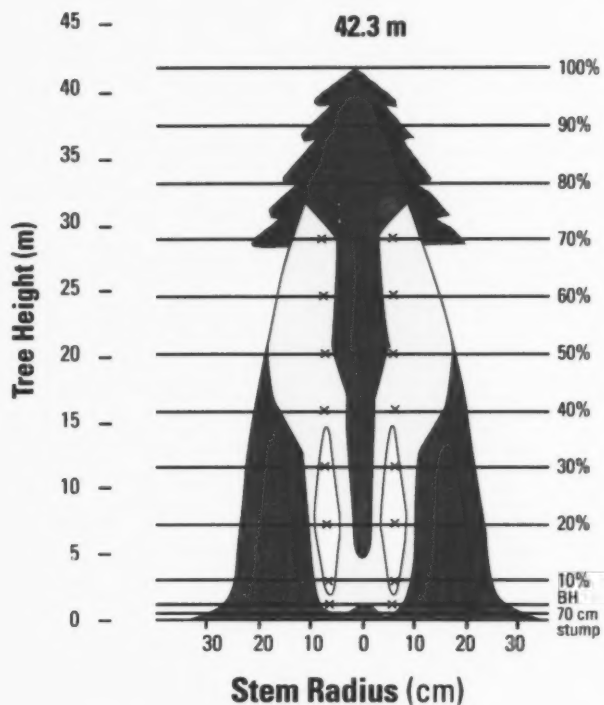
OVERHEAD 83

Yearly ring density trends at six sampling heights are shown for the Port Hardy 650 stems/ha location. We can see that by age 30, at all sample heights, wood density is >0.41 , and by age 50 these trees are producing "Douglas-fir-like wood" (= and $>$ than 0.45 relative density).

The bottom half of the graph shows "smoothed" trendlines.

Lake Cowichan

Summary of 13 trees (450 stems/ha)



Relative Density Zone: <0.40 0.40 – 0.43 >0.43 × minimum density

OVERHEAD 84

Average tree-stem profiles and extent of the live crown were drawn with the help of field measurements; tree height, base of live crown, and stem diameters at 12 sampling heights (from stump to 90% tree height). Density zones of “less than species average” (<0.40), “species average” ($0.40-0.43$), and “higher than species average” (>0.43) were mapped with the use of pith-to-bark trends, as shown in the previous overhead.

Stem profiles and relative density distributions are shown by “stem radius” and by “basal area”. Of course, an argument can be made for both versions, but the basal area-weighted depiction shows the relative amounts of wood more realistically. For example, the pith-associated high-density wood gets “equal billing” with the outer wood beneath the bark, of the same radius, by the first version (stem radius). Using the inner 10 cm radius from stump-to-30% tree height, let's calculate the basal area: $10^2 \times 3.14 = 314 \text{ cm}^2$. If we calculate the basal area of the next 10 cm in radius, from 10 to 20, we find three times more wood, 942 cm^2 .

So much for the rationale of data presentation! Now, what do these stem profiles mean in terms of wood quality and product potential?

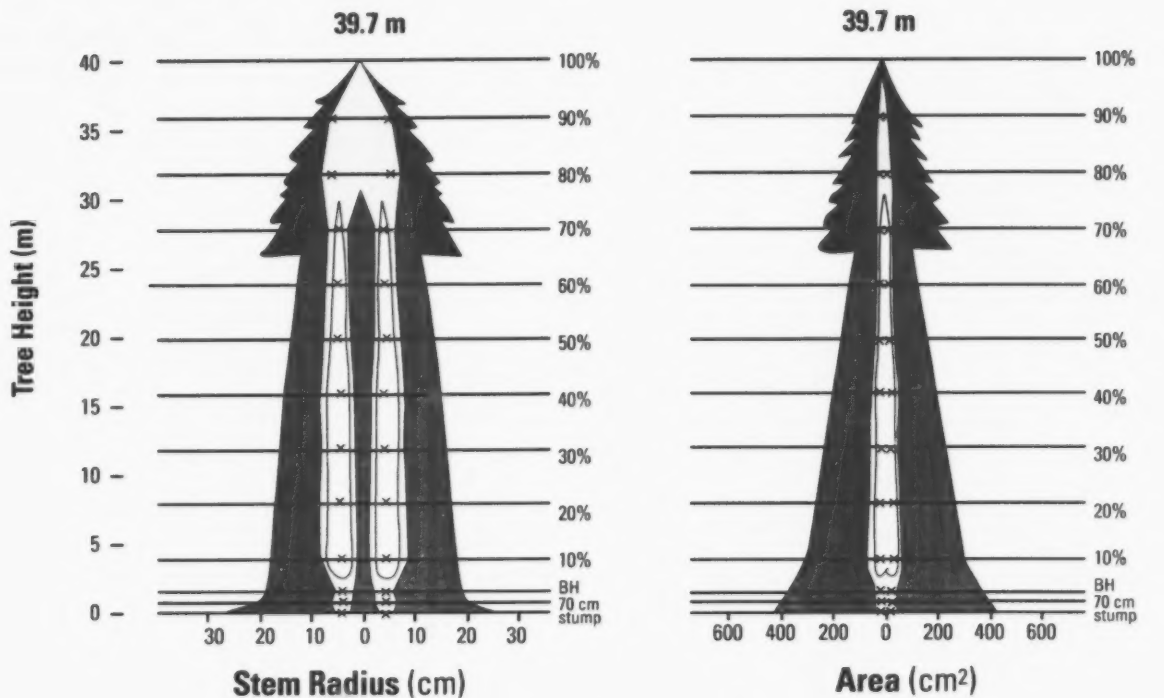
It is encouraging to note that even in the Lake Cowichan sample, with only 450 stems/ha, there is 61% high-density mature wood by volume. (As noted previously, the pith-associated high-density wood is definitely juvenile in nature, because of its high fibril angle, short fibre length, etc.)

This outer mature-wood shell is about 15 cm thick and 17 m long, a lot of wood for producing high-density solid wood products like MSR lumber, laminated veneer lumber (LVL), furniture wood, Parallam, etc. Even the top half of the stem falls within the $0.40-0.43$ relative density range; not all that different from the old-growth average of 0.42 .

This information will be useful in allocating raw materials for appropriate secondary products manufacturing decisions, for dimensional lumber, composite products, and for pulping.

Port Hardy M22

Summary of 13 trees (1000 stems/ha)



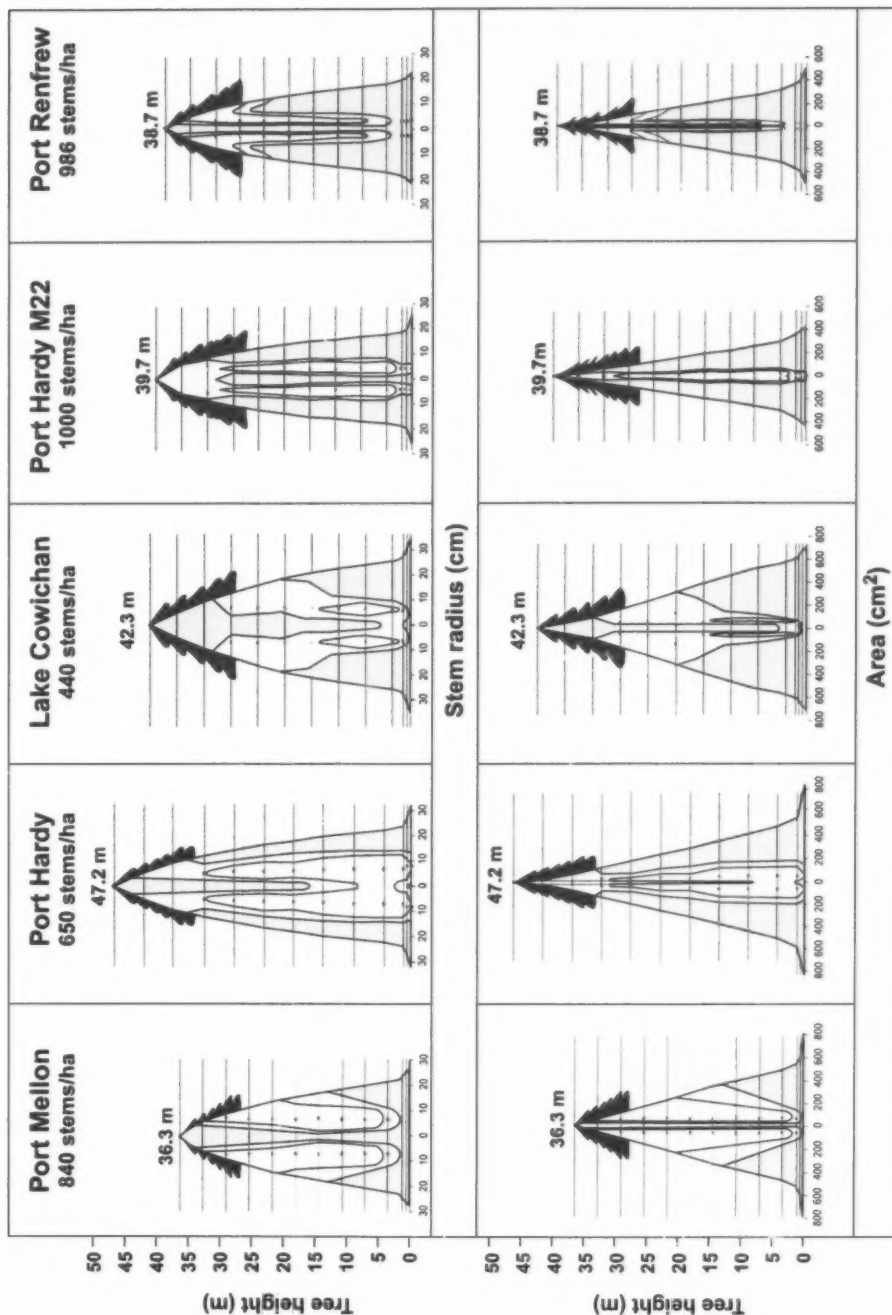
Relative Density Zone: <0.40 0.40 – 0.43 >0.43 × minimum density

OVERHEAD 85

The Port Hardy M22 samples, with 1000 stems/ha has a smaller juvenile-wood cylinder than the Lake Cowichan trees. Here the juvenile-wood cylinder is less than 10 cm in radius, and the high-density mature wood extends up into the live crown.

Based on detailed cruise data, these 90 year old western hemlock trees have produced 16 m³ of wood per hectare per year.

Relative density zones: ☐ <0.40 ☐ 0.40–0.43 ☐ >0.43 * Minimum density



OVERHEAD 85A

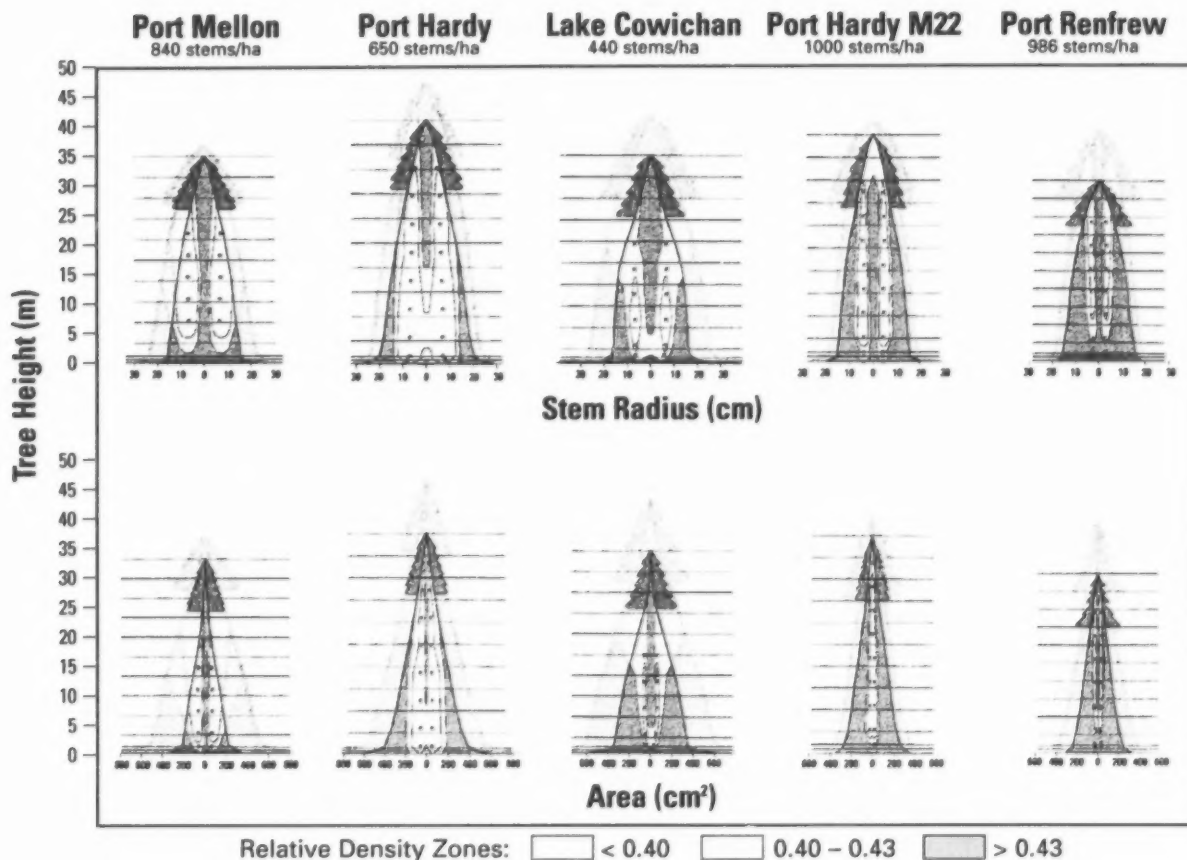
Average tree profiles with the extent of the live crown and stemwood density zones are shown here for the five sampling sites. The same data are shown (as before) by stem radius and by basal area.

The volume-weighted juvenile/mature wood distribution is shown in the bottom half of this overhead. This evaluation identified, left to right, 68, 41, 39, 30, and 30% juvenile wood. In this ranking, the Port Mellon sample appears to be an anomaly, because of the relatively high number of 840 stems/ha at this location.

The Port Mellon samples also had the least amount of outer mature wood, >0.43 relative density. This anomaly caused a lot of concern, and led to a follow-up study at the Haney Research Forest, where Western hemlock trees were planted at the same location to different densities (3 × 3, 9 × 9, and 12 × 12 feet spacing).

Average Tree Stem Profiles and Density Distributions

(summary of 13 trees per site at age 60 superimposed onto 90 year old trees)



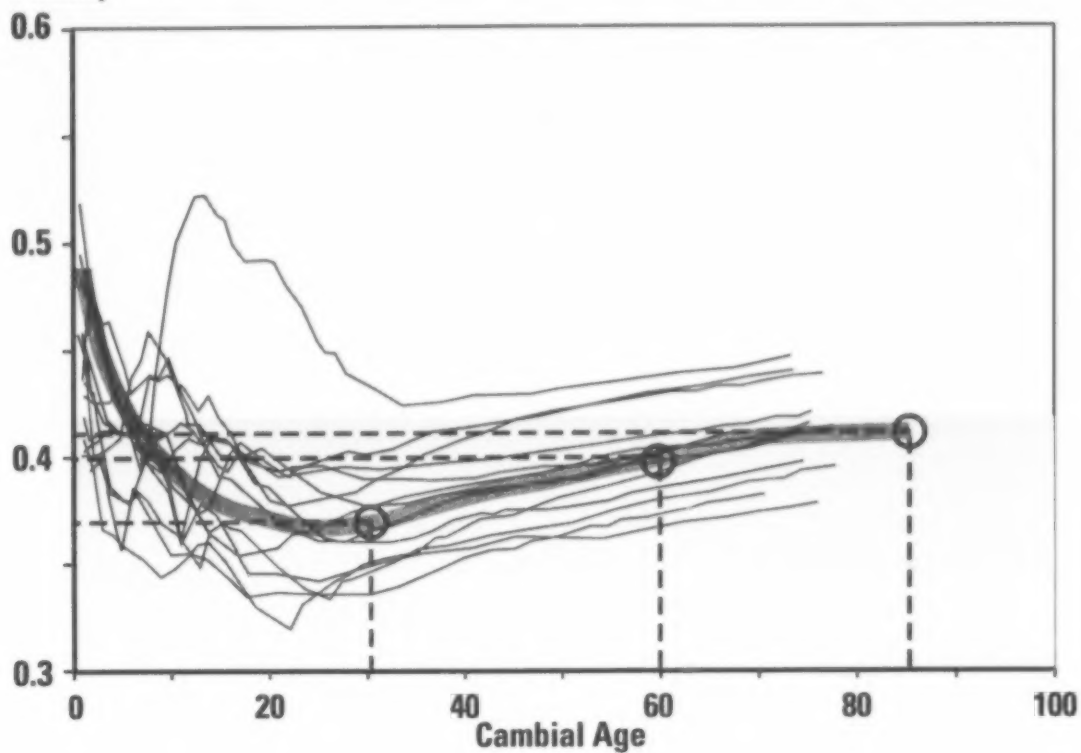
OVERHEAD 86

At Forintek we have a very strong client pull for investigating basic wood properties at much younger tree ages. For example, for western hemlock the financial rotation (as opposed to biological rotation) was estimated at 35–38 years of age. Actually this train of thought starts to make some sense when one looks at a large number of cross-sections from second-growth western hemlock.

In response to membership client-pull we “terminated tree growth” at age 60, to show how these 90 year old trees looked back then. The difference in tree height and diameter is at the expense of high-density mature wood.

Western Hemlock Port Hardy

Total Stem
Density

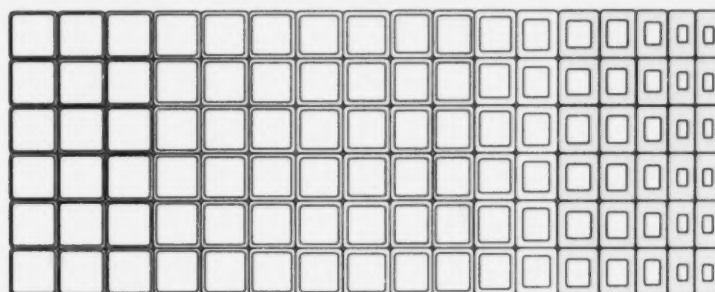
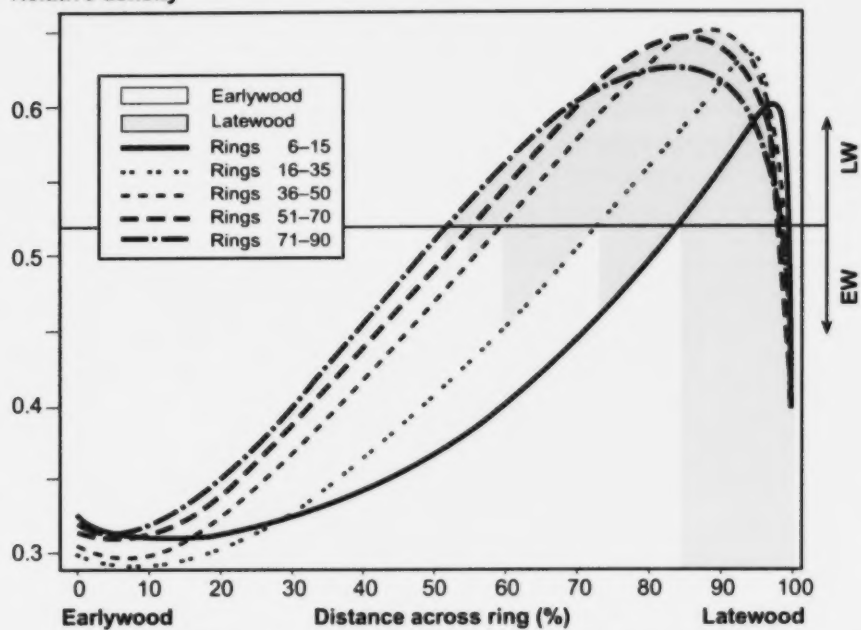


OVERHEAD 87

Through the integration of tree height measurements and X-ray densitometric ring width and ring density measurements, weighted average stemwood densities can be calculated on a yearly basis. This overhead shows the relationship between total stemwood density and total stemwood volume for the Port Hardy (650 stems/ha) sample. Note that although the smallest tree, with 1.3 m³ total stem volume is also the most dense (0.44 relative density), the largest tree, with 5 m³ stem volume, is not the least dense.

Also shown is total stemwood density from age one to age 80. Minimum stemwood density of 0.37 was reached at age 30. By age 60 stemwood density is 0.40, and by age 80 it is 0.41. The difference or range between the most and least dense tree is about 0.07 density units.

Relative density



Schematic of one annual ring
(approximately 230 times magnification)

OVERHEAD 87A

Intra-ring density profiles are shown for Port Hardy (650 stems/ha) and Port Hardy M22 (1000 stems/ha) tree samples for all 12 sampling heights. In addition to the yearly profiles, average profiles were prepared at each sampling height by summarizing all the rings from pith-to-bark.

Yearly minimum density values in the earlywood zone show a declining trend from pith to age 10, then level off and range mostly between 0.25 and 0.30. Maximum ring density values show little change from pith-to-bark, and range between 0.6 and 0.7. Therefore, because the lower and upper of density are well defined in a narrow range, it is the proportion of latewood that will determine the relative density of each annual ring.

The average ring density profiles show a decreasing trend in latewood width from the stump to the 90% tree height. This supports the decreasing disk density trends from stump to top, as discussed earlier.



OVERHEAD 87B

This illustration shows intra-ring density profiles for the BH samples of 166 trees from five locations of 90 year old western hemlock trees. To help with orientation, the schematic of one complete annual ring is shown at the bottom of the graph. The superimposed intra-ring density profiles were produced by summarizing rings 6–16 (juvenile zone), 16–35 (transitional zone), 36–50, 51–70, and 71–90 (the last three intervals from the mature zone). Ring width was standardized for ease of comparison of density range (between earlywood and latewood) and percent latewood width. For these interval summaries minimum ring density ranges between 0.29 and 0.32, while maximum latewood density is between 0.58 and 0.65.

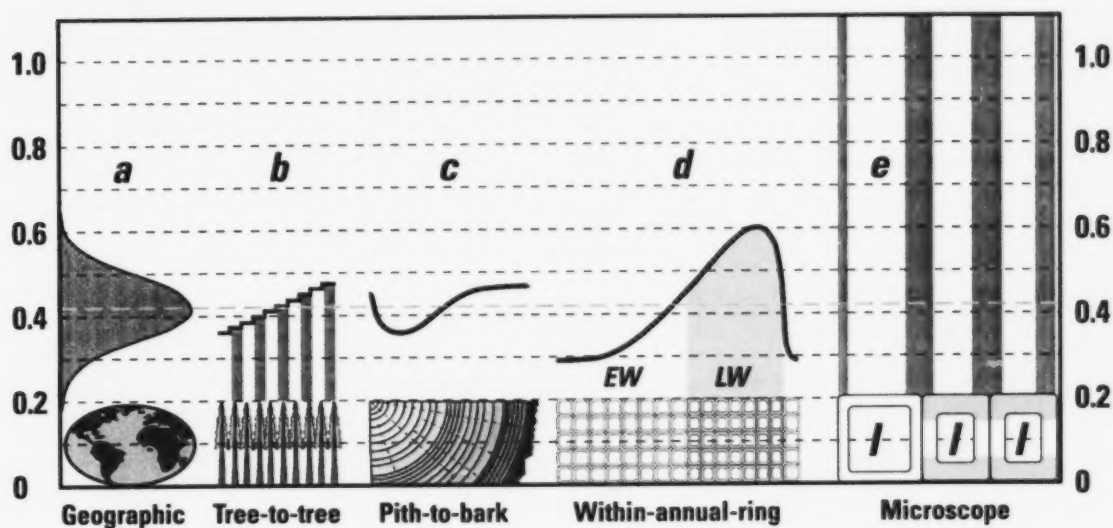
The first interval, rings 6–15, the average ring contains only 15% latewood, and it was 3.92 mm wide. Latewood width increases from pith-to-bark from 15% to 28, 40, 45, and 48% from rings 6–15 to rings 16–35, 36–50, 51–70, and 71–90, respectively. For the same time intervals average ring width was 3.92, 2.64, 1.92, 1.44, and 1.1 mm

The most important feature of these western hemlock intra-ring density profiles explains the excellent machinability property of the species; there is very little low density earlywood and high density latewood. Note how from the very beginning of the annual ring, there is an immediate gradual increase in density. In other words, there is no substantial amount of low density earlywood, as one might find in Douglas-fir and western redcedar. This “robust” transitional earlywood will make the wood tougher to wear-and-tear in furniture, panelling, doors, windows, etc.

Density homogeneity will help in veneer peeling and wood turnings as well.

Global to Microscopic View of Density Distribution in Western Hemlock

Solid Cell
Wall Relative
Density 1.1



OVERHEAD 88

This overhead should be shown and discussed by revealing the five panels one-by-one.

First, **geographic/global** average stemwood basic relative density of these 90 year old second-growth western hemlock trees was 0.426, compared with the old-growth standard of 0.42.

Second, **tree-to-tree** average stemwood density ranged from 0.36 to 0.51 for the 65 trees. This variability in stemwood density is very similar to the old-growth western hemlock norm of 10% coefficient of variation (mean 0.42, range 0.34–0.50).

Third, **pith-to-bark** yearly average ring density trendline is similar to a check-mark, as was shown in Overheads 82 and 83. This has implications for earlier harvests, such as in commercial thinnings or partial cuts; if trees are harvested at a younger age, stemwood density will be lower than the 0.42 old-growth standard.

Fourth, **within-annual-ring** density trends (as discussed in Overhead 87b).

Fifth, **microscopic** density distribution; in this realm, basic relative density ranges from the absolute minimum of zero (in the lumen), to 1.1 in the solid wood substance of the cell wall material.

(A good mental exercise: discuss and rationalize the density difference of the solid wood substance in the oven-dry (1.53) and the fully water saturated condition (1.1). Of course, this implies that a solid block of oven-dry wood-substance, with no air in it, will sink in water more readily than a wet one.)

Western Hemlock

Log Grade			Old-growth	Second-growth
small Ø	D	log length	\$ 10,000	\$ 4,000
12 – 36 in.	H	16 – 24'	12,000	8,000
15 – 36 in.	I	12 – 14'	12,000	15,000
4 – 11 in.	J	16 – 24'	5,000	20,000
4 – 14 in.	X	8 – 14'	6,000	4,000
15 – 36 in.		8 – 10'		
4 – 36 in.	Y	< 8'	5,000	4,000
Total			\$ 50,000	\$ 55,000

- Stand volume in second-growth 150 – 200m³ higher than in old-growth

WFPL – North Vancouver Island

OVERHEAD 89

Some of the naturally regenerated second-growth western hemlock stands are extremely productive. Total wood production of 15–20 m³ of wood/ha/yr is not uncommon. For example, the 85 year old M22 site at Port Hardy had a total volume of 1 372 m³. Yearly average wood volume production was 16 m³/ha. At another location, near Port McNeill, FERIC and MacMillan Bloedel were doing commercial thinning in 50 year old western hemlock. Productivity rates in five different plots were 17.2–23 m³/ha/yr. Site index was 31–33 m (at age 50). Number of trees per hectare ranged from 956 to 1678. Average height over diameter ratio was 102–124. From the same general area (north Vancouver Island) Western Forest Products found similar productivity rates.

This picture was taken by Dr. Hamish Kimmins. On the left-hand side of the picture we can see a vigorous second-growth, while on the right-hand of the picture there is an old-growth western hemlock stand.



OVERHEAD 90

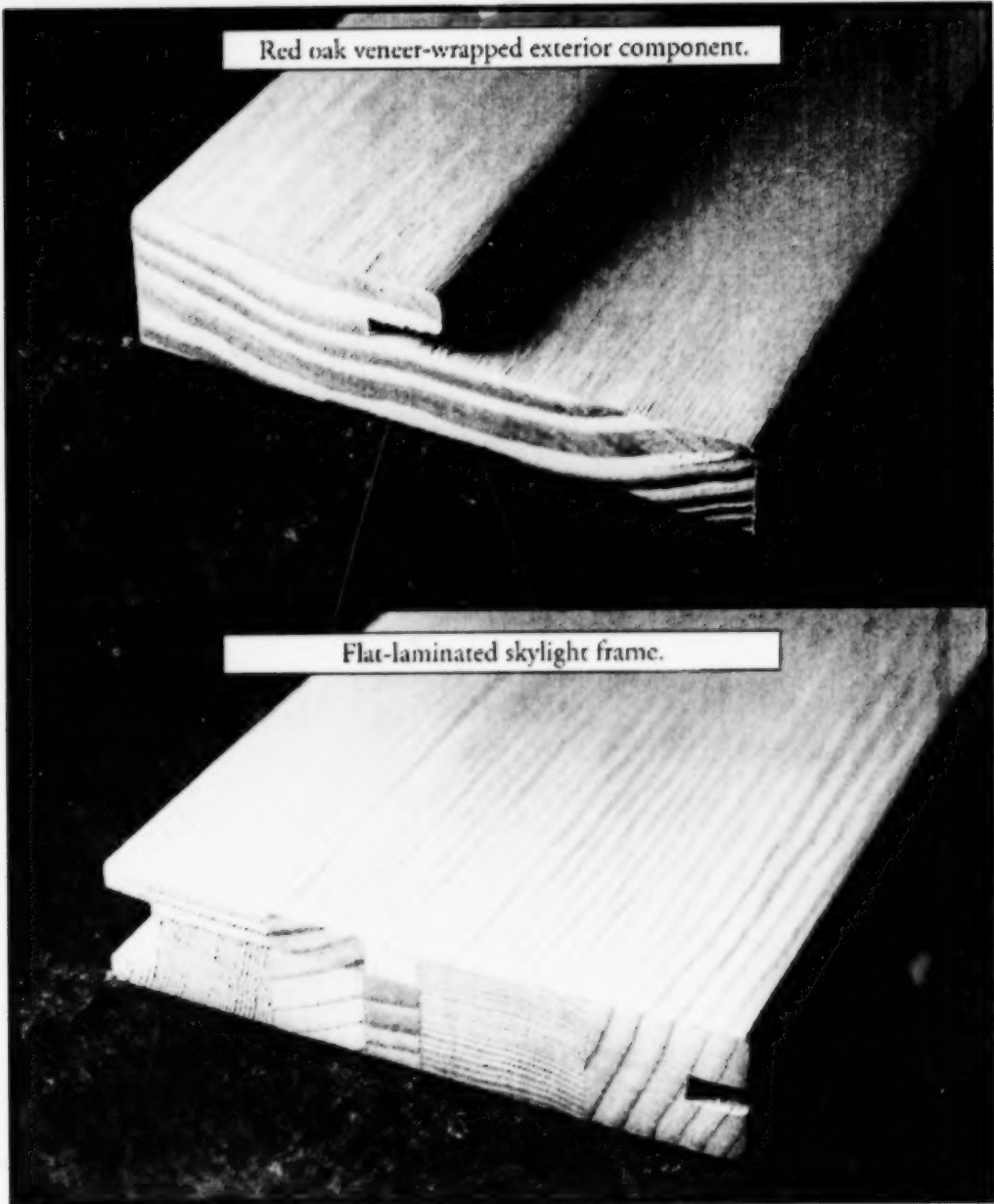
Engineered wood products—which can be defined simply as any wood that has been taken apart and reassembled in a manner that will yield a useful product with predictable engineered properties at competitive value—are the fastest growing segment of the building materials industry in North America and the world.

The evolution of **composite products and engineered wood products** in North America over the last 60 years began with the introduction of plywood in the 1930s. This was followed by fibre cement board in the late 1940s, particle board in the late 1950s, oriented strand board or wafer board (OSB) in the early 1960s, and medium density fibreboard (MDF) in the 1970s. Laminated veneer lumber (LVL) and I-joists ("silent floor") were introduced in the late 1970s, but they did not get the wide public acceptance until the 1990s. Finger-jointing green lumber at industrial production speeds was developed by my colleagues at Forintek in the mid 1970s. Parallam® (parallel strand lumber) was developed in the early 1980s. One of the most recent development was Timberstrand® (laminated strand lumber), in the 1990s.

These were the major product lines, but there were other incremental developments as well, like in finger jointing, edge-gluing, and veneer-wrapping MDF, lower grade woods, plastics, and even metals.

Recent research and development has produced many viable products combining wood with other materials. Wood fibre-plastic composites are used extensively in the automobile industry as a substrate for interior door panels, roof headliners, seat backs, rear decks, and trunk liners (vinyl, carpeting and other coverings are applied over the substrate). Reinforced glued laminated timber beams utilize high-strength fibre additives in a thin plastic matrix, which are added with the gluing procedure. The new product has economic advantages because the reinforcement allows smaller cross sections than conventional glulam timbers.

What about the future? While North America formerly led in the development of plywood, Malaysia and Indonesia now dominate in this area. Europe was and is the leader in developing particleboard, MDF and fibre-cement board. Currently, North America leads in the production of OSB, LVL, Parallam® and I-joists. Market conditions are, however, changing very rapidly in the face of global technology, changes in wood supply economics due to plantations and new hybrid species, and highly mobile capital.



Red oak veneer-wrapped exterior component.

Flat-laminated skylight frame.

OVERHEAD 91

After explaining the overhead, show some examples of MDF moldings (paired with their wooden equivalents and appropriate prices!), "silent floor", finger joints, Parallam®, edge-glued pine shelving, etc.

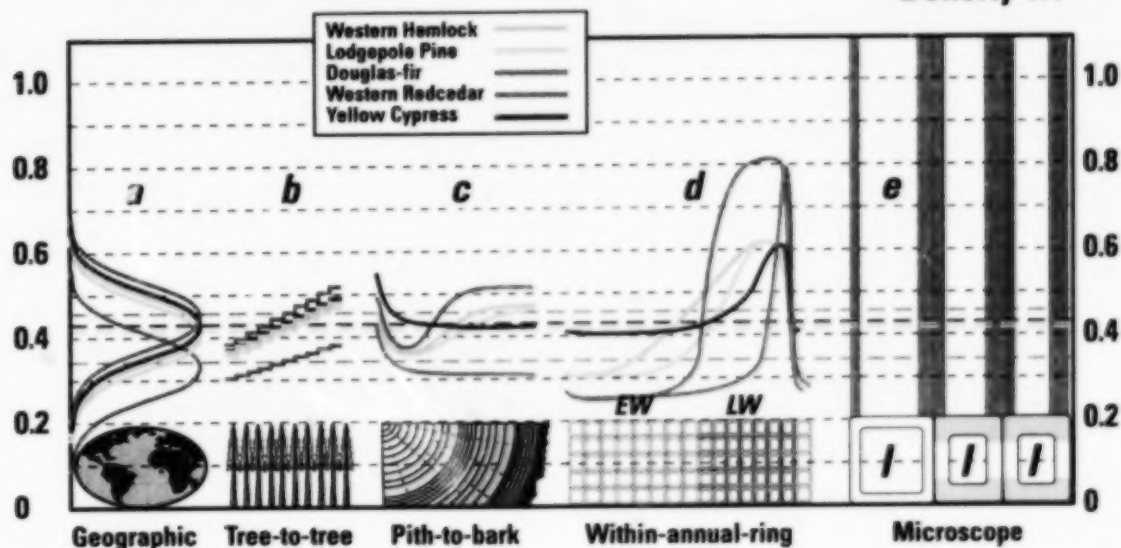
From time-to-time there were serious problems with some composite products. These problems arose usually because of poor quality control. In the early to mid 1970s large glulam beams were showing signs of delamination. The problem was traced back to uneven heating and extremely hot heating platens. Latent heat in the wood (transferred from the platens) was used to accelerate curing of the glue. Overheating weakened the wood surface (the bonding sites), reducing shear strength to critical levels. In retrospect, not enough testing and quality control was carried out with that project. Other problems include the fire retardant treated plywood roof decking that "cooked apart" in the New York summer heat. More recently, some composite siding products were experiencing difficulties in the USA Northeast; OSB siding got saturated with water and got swollen up (not a good thing to do). More resin and testing could have prevented a \$50 000 000 lawsuit.

Ask the workshop participants for their own company's and personal experiences with composite products. Where do they see the future trends and markets?

In closing our discussion on composite wood products, it is well to remember that the groundwork for the technology that underlies the development of engineered wood products was established long ago. The wood science and technology community was at work developing new products long before the crisis surrounding harvest limitations developed. It has been very fortuitous that as old-growth timber has become less available, new engineered wood products have been developed to meet the demands of the 21st century.

Global to Microscopic View of Density Distribution in BC Tree Species

Solid Cell
Wall Relative
Density 1.1



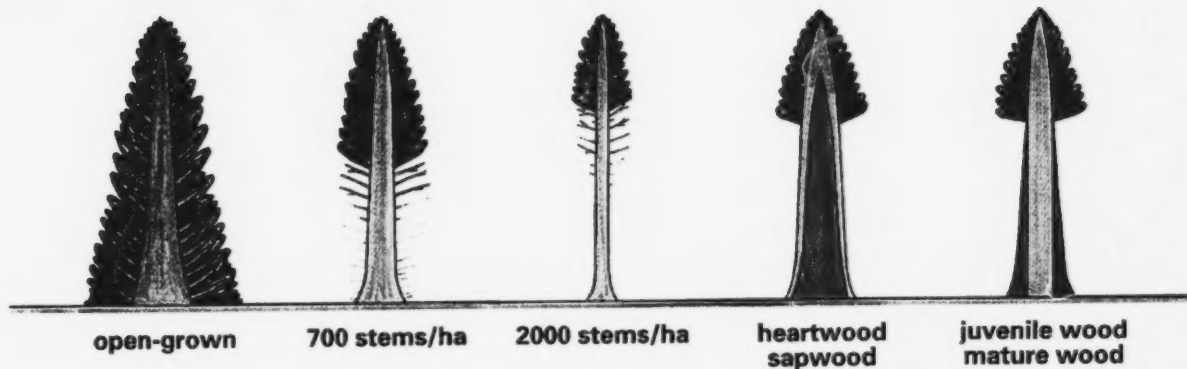
OVERHEAD 92

We have come to the end of our wood quality workshop. We started out with an overview of global trends in wood supply and demand, and concluded with composite products. Central to our discussion was always wood. Different kinds of wood. About half a dozen tree species were discussed in some detail, from the global to the microscopic perspective.

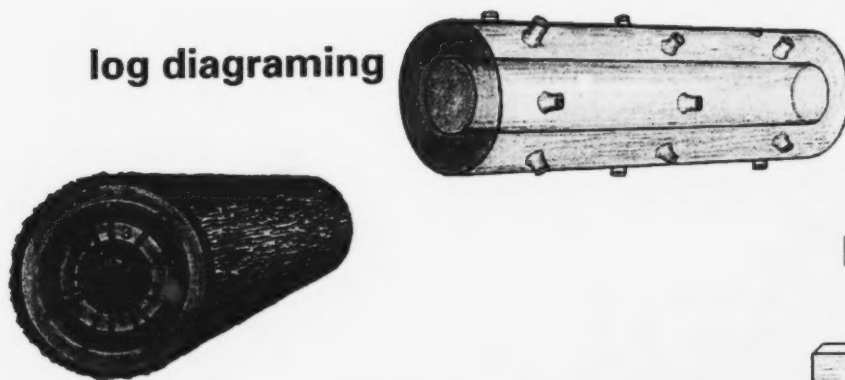
Show this overhead by covering up panels **b**, **c**, and **d**. By revealing **a** and **e** only, review the basic premise that all solid wood substance has a basic relative density of 1.1. Therefore, the species-to-species differences in average density, shown in

panel **a**, must be the result of the proportion solid wood substance to air spaces in the wood. Proceed with revealing the other three panels one-by-one, summarizing and contrasting species-to-species differences (refer to SP No. 34 for additional detail).

Wood Quality is Related to Measurable Stand...

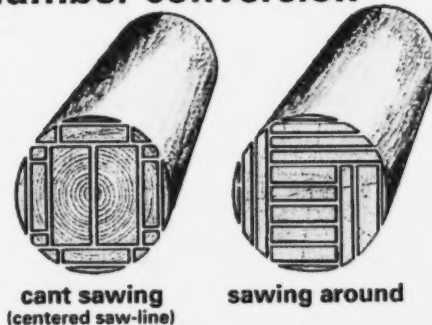


log diagramming

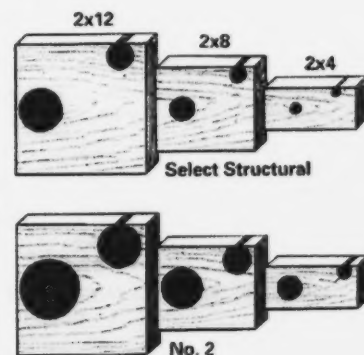


- 1) clear: \$1,250 - 4,000/M
- 2) near clear: \$600 - 1,000/M
- 3) appearance: \$450 - 800/M
- 4) structural: \$350 - 500/M
- 5) low grade: \$250 - 350/M

lumber conversion



lumber grading

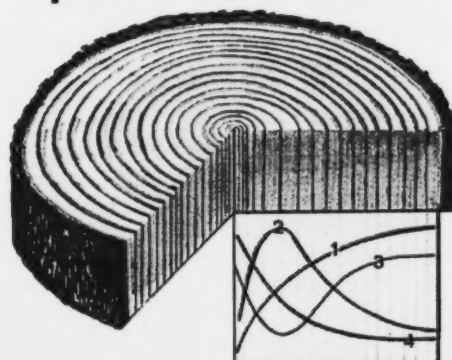


OVERHEAD 93

This workshop has demonstrated that wood quality is related to measurable stand, tree, log, lumber, and fibre characteristics. We have seen the impact of stocking and stand density on stem size, taper, branch size, crown size, rate of crown recession, and wood juvenility. We talked about the major tissue types in a tree stem and related their importance to the forest products industry (both solid wood products and the pulp and paper sector). Log diagramming, lumber conversion, and lumber grading was referred to a number of times, as these concepts relate to the resource. We talked about commodity products, and higher value products in the context of MSR lumber, truss manufacturing, pressure treatment with preservatives, secondary manufacturing, and the ever increasing need for proper lumber drying.

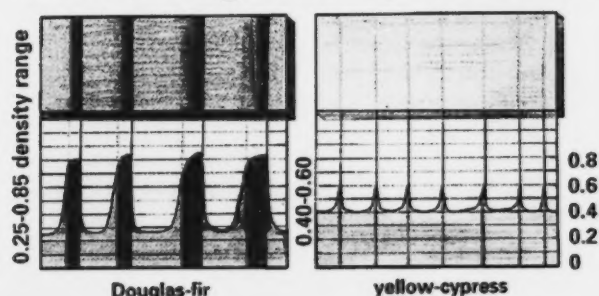
...Tree, Log, Lumber and Fibre Characteristics

pith-to-bark trends



- 1 fibre length
- 2 ring width
- 3 ring density
- 4 fibril angle

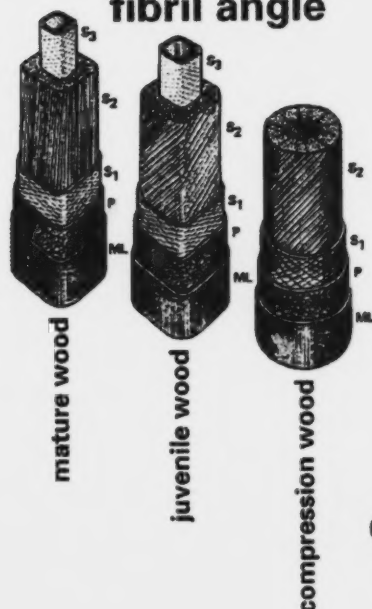
within-ring density variation



Douglas-fir

yellow-cypress

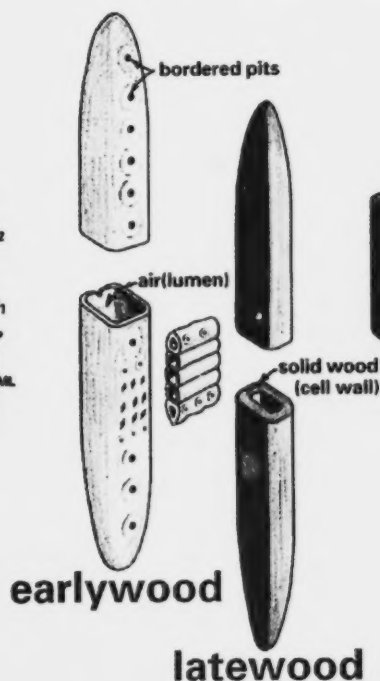
fibril angle



mature wood

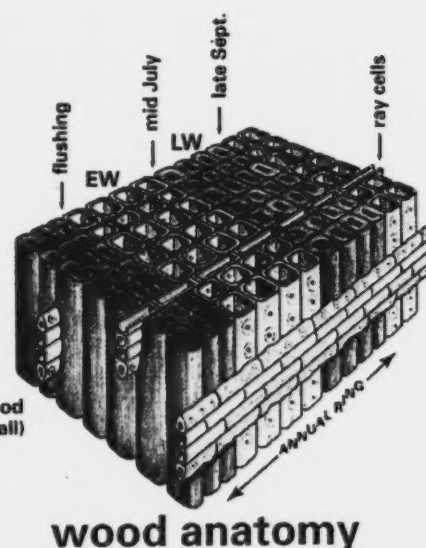
juvenile wood

compression wood



earlywood

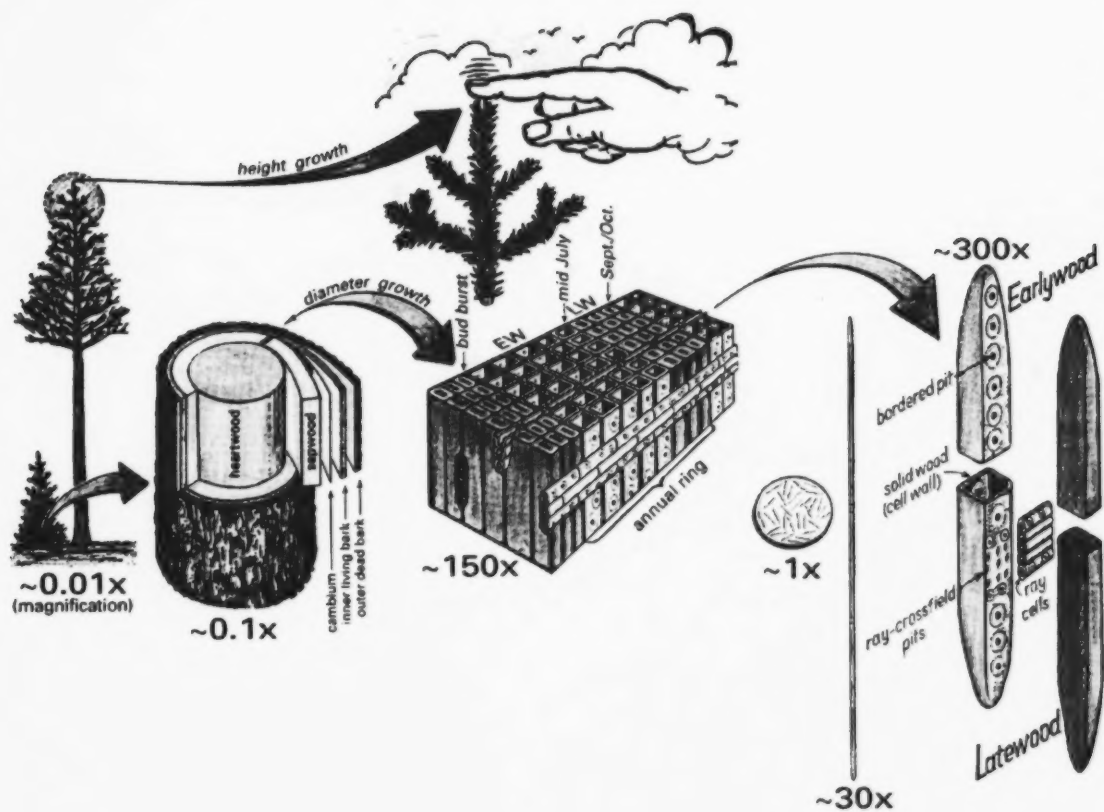
latewood



wood anatomy

OVERHEAD 94

Special attention was paid to characterizing the extent of juvenile wood (crown-formed wood) through examining pith-to-bark trends in fibre length, extractives, ring width, ring density, fibril angle, and longitudinal shrinkage. We emphasized that not all species have low-density juvenile wood, but all species have shorter fibres, larger fibril angles, and dimensional stability problems near the pith. The microscopic structure and fibre morphology of earlywood and latewood were discussed in terms of strength and stiffness, machining properties, and paper sheet formation.



OVERHEAD 95

You were teased (and perhaps insulted) about the basics like: How do trees grow? When do trees grow? What are tree rings? What are the major tissue types and their role in a tree stem? Why can't we see wood fibres with the naked eye? Why should we concern ourselves with wood structure, tree growth, and wood quality?

We established time and again that qualities of wood that we appreciate in various end-uses differ by species, and are linked to basic properties. Because silvicultural practices can alter these properties, we have an obligation to explore and understand all of the linkages involved. Only then can we hope to ensure that the quality of wood from managed stands remains equal to that of our natural forests.

Thank you for your attention and patience!

Wood Quality...

Impact on Product Yields, Grades and Value

WORKBOOK



Canada

CANADA - BRITISH COLUMBIA
PARTNERSHIP AGREEMENT ON
FOREST RESOURCE DEVELOPMENT
FRDA II

BC



Forintek
Canada
Corp.



BC Forestry
Continuing
Studies
Network



Big or Small Trees, Fast or Slow Growing Trees?



Canada
FOREST SERVICE
RESEARCH & DEVELOPMENT
NORTH AMERICAN FOREST
PRODUCTS



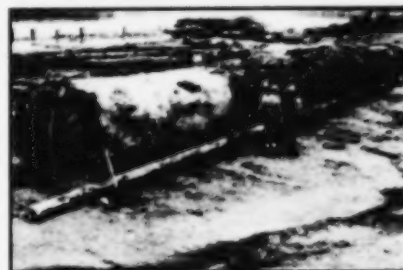
Wood Quality... Impact on Product Yields, Grades and Value



Then
&
Now



Wood Quality... Impact on Product Yields, Grades and Value

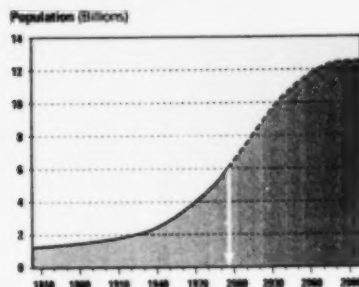


Wood Quality... Impact on Product Yields, Grades and Value
© 2000 by the Forest Products Research Society

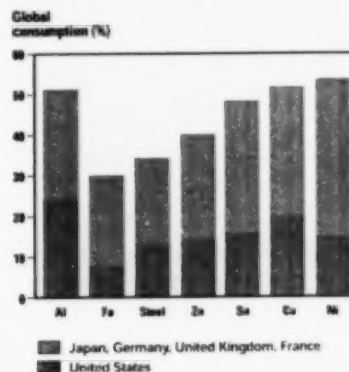


Wood Quality... Impact on Product Yields, Grades and Value
© 2000 by the Forest Products Research Society

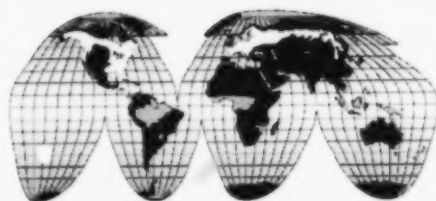
World Population 1850 to 2100



Global Consumption of Raw Materials by 10.3% of Global Population



Our Forests



- Temperate coniferous and mixed forests
- Tropical rain forests

Wood Quality... Impact on Product Yields, Grades and Value



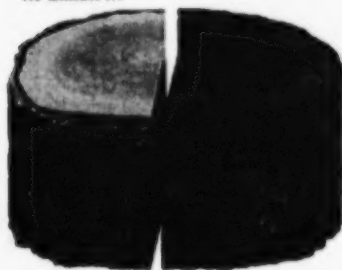
Wink Sutton holds
"The Wedge";
a 1.8 litre piece
of wood that
represents the
average amount
of wood used
each day by each
person on earth.

(Based on FAO figures: total wood harvested
population of earth)

Annual World Consumption of Wood

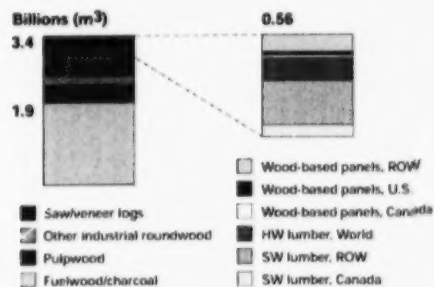
Industrial
Roundwood
1.7 billion m³

Fuelwood
1.8 billion m³



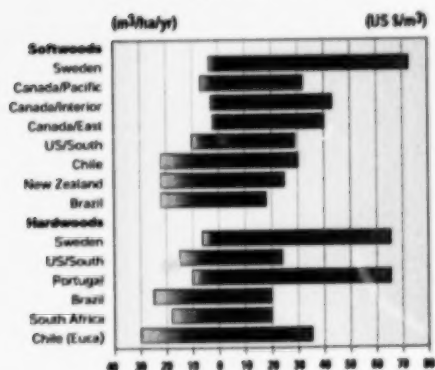
Wood Quality... Impact on Product Yields, Grades and Value
10/10/10 10/10/10

Global Production of Fibre



Source: FAO

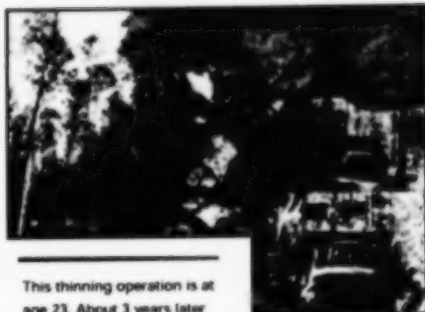
Wood Quality... Impact on Product Yields, Grades and Value
10/10/10 10/10/10

Growth and Mill Delivered
Cost of Pulpwood - 1/91

Wood Quality... Impact on Product Yields, Grades and Value



Wood Quality... Impact on Product Yields, Grades and Value



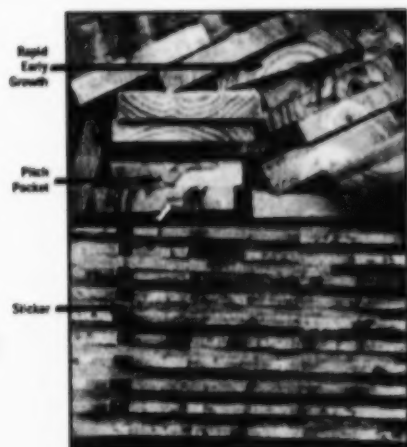
This thinning operation is at age 23. About 3 years later this stand will be clearcut and replanted.

Wood Quality... Impact on Product Yields, Grades and Value
© 1998 WPA, Inc. WPA 100-1000

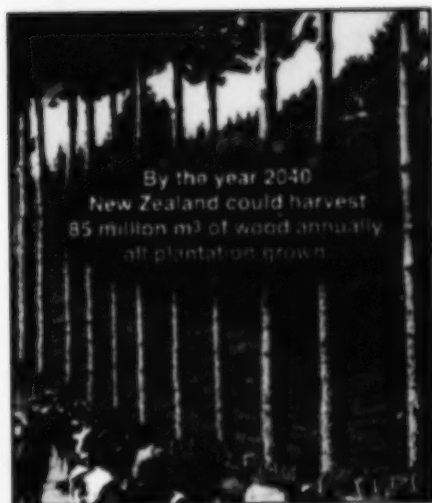


26-year-old Caribbean pine hybrid.

Wood Quality... Impact on Product Yields, Grades and Value
© 1998 WPA, Inc. WPA 100-1000



Wood Quality... Impact on Product Yields, Grades and Value
© 1998 WPA, Inc. WPA 100-1000

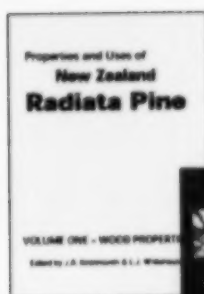


By the year 2040
New Zealand could harvest
85 million m³ of wood annually
all plantation grown

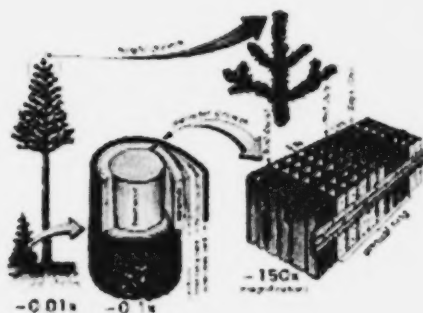
Wood Quality... Impact on Product Yields, Grades and Value
WORLD WOOD COUNCIL



Wood Quality... Impact on Product Yields, Grades and Value
WORLD WOOD COUNCIL



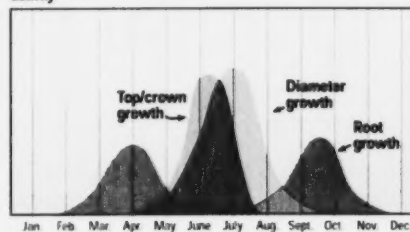
Wood Quality... Impact on Product Yields, Grades and Value
WORLD WOOD COUNCIL



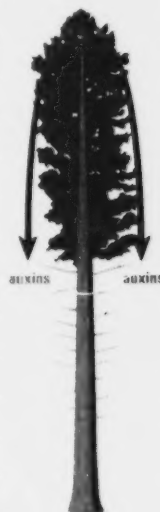
Wood Quality... Impact on Product Yields, Grades and Value.

Phenology of Tree Growth

Relative activity



Wood Quality... Impact on Product Yields, Grades and Value.

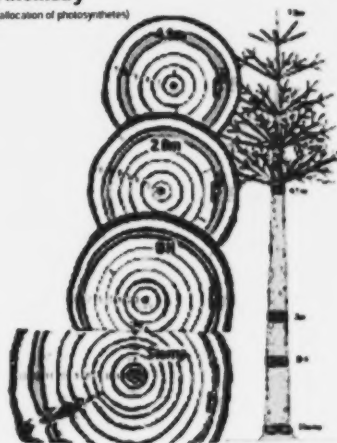


- Terminal shoot and vigorous leaf formed portions of the crown foliage produce growth regulating hormones (auxins) and photosynthate.
- Lateral and downward translocation of auxins to reach lower stem.
- In spring radial growth begins first at the top of the tree and proceeds gradually downward = more EW and wider rings in upper crown region near pith.
- Less EW and smaller rings at the base where rings are far from pith.
- Transition to LW occurs first near the base, farthest from the source of auxin supply and proceeds upward.
- The destiny (and density) of an individual fibre is thus determined by its relative position; its distance from the active live crown region and the time of its formation (season).

Wood Quality... Impact on Product Yields, Grades and Value

Allometry

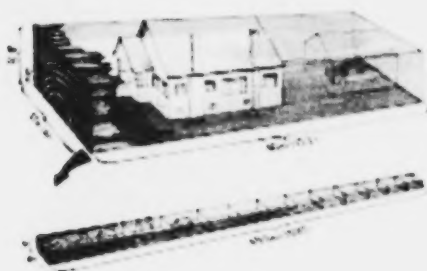
(allocation of photosynthates)



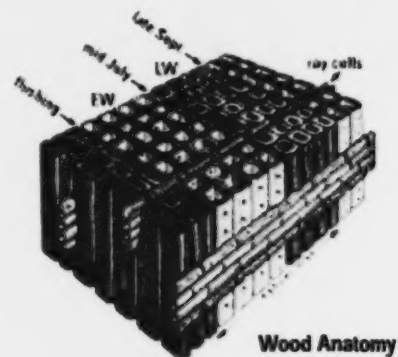
Wood Quality... Impact on Product Yields, Grades and Value



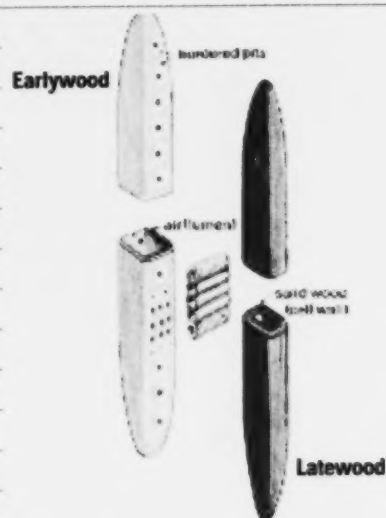
Wood Quality... Impact on Product Yields, Grades and Value.
Photo courtesy of the Wood Handbook



Wood Quality... Impact on Product Yields, Grades and Value.
Photo courtesy of the Wood Handbook



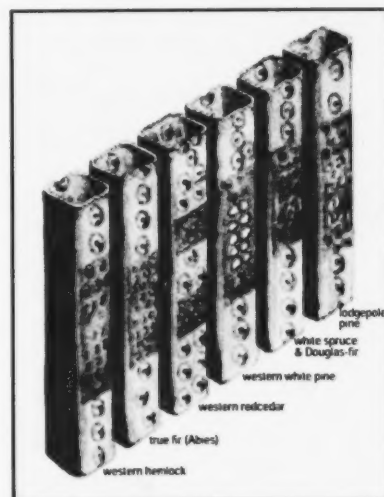
Wood Quality... Impact on Product Yields, Grades and Value
© 2000 Forest Products Research Society



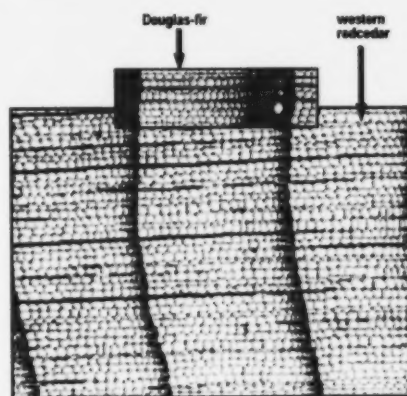
Wood Quality... Impact on Product Yields, Grades and Value
© 2000 Forest Products Research Society



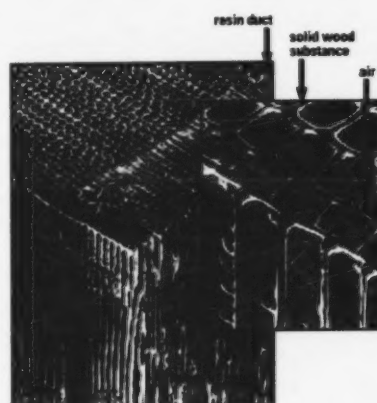
Wood Supply... almost as Perfect. Yours. Capital and More



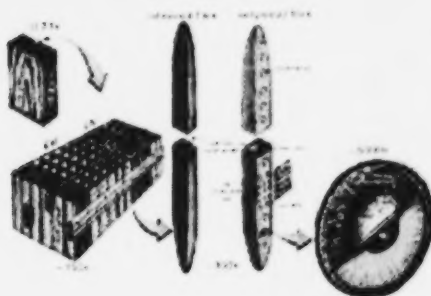
Good Quality... Impact on Product Value, Grades and Uses



Wood Quality - Impact on Product Yields, Grades and Value
WOOD QUALITY IN THE WOOD MARKET



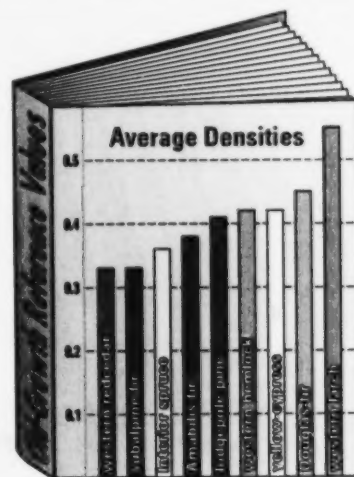
Wood Quality - Impact on Product Yields, Grades and Value
WOOD QUALITY IN THE WOOD MARKET



Wood Quality... Impact on Product Yields, Grades and Value

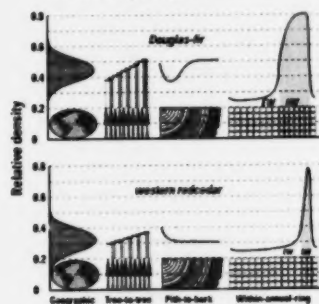


Wood Quality... Impact on Product Yields, Grades and Value



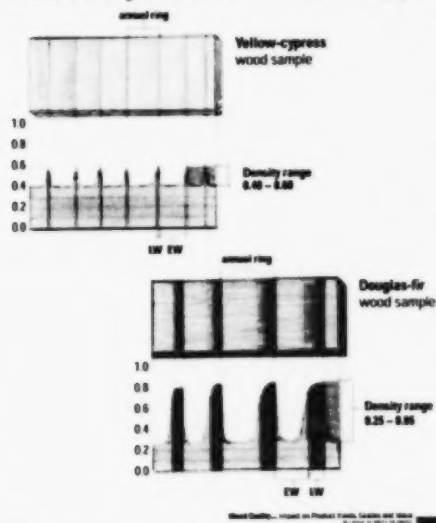
Wood Quality... Impact on Product Yields, Grades and Value
Revised 11/04/11 by BCC

Global to Microscopic View
of Density Distribution in
BC Tree Species



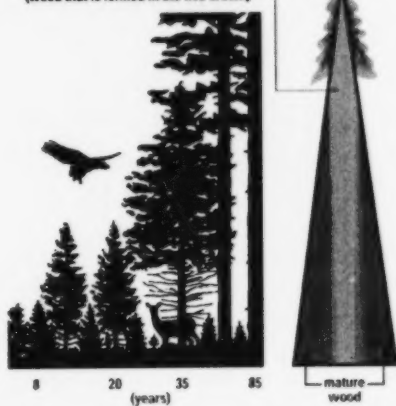
Wood Quality... Impact on Product Yields, Grades and Value
Revised 11/04/11 by BCC

Wood Density Variation within Growth Rings



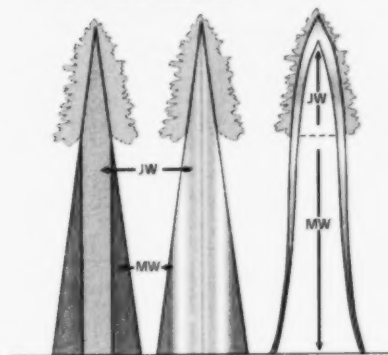
Juvenile Wood

(wood that is formed in the live crown)



Wood Quality... Impact on Product Yields, Grades and Value

Juvenile Wood (JW) and Mature Wood (MW)

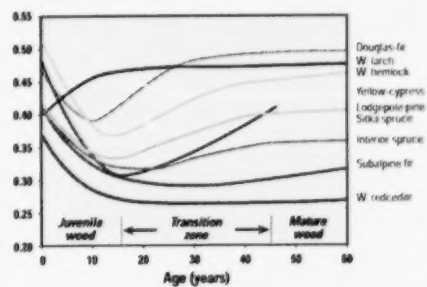


Wood Quality... Impact on Product Yields, Grades and Value

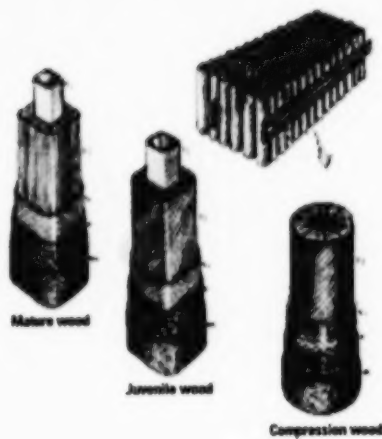


Wood Quality... Impact on Product Yields, Grades and Value
© 1998 BC Forest Sciences Centre

Relative Density at BH of
Rapidly Grown B.C. Woods

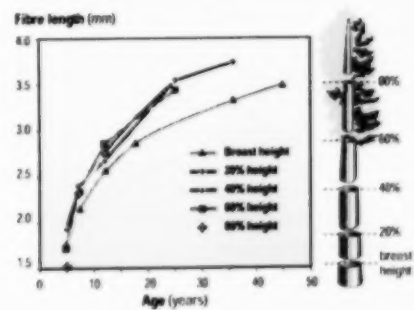


Wood Quality... Impact on Product Yields, Grades and Value
© 1998 BC Forest Sciences Centre

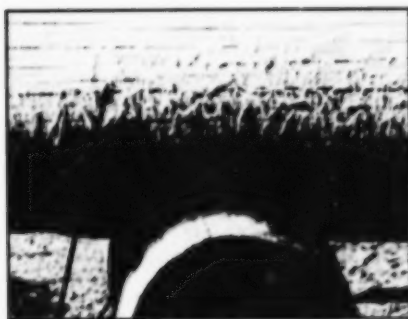
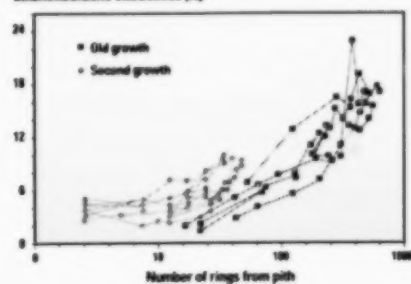


Wood Quality - Impact on Product Yields, Grades and Value

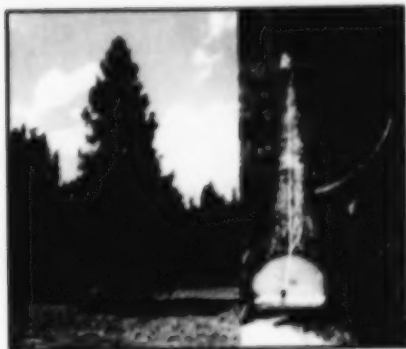
Second Growth Douglas-fir



Wood Quality - Impact on Product Yields, Grades and Value

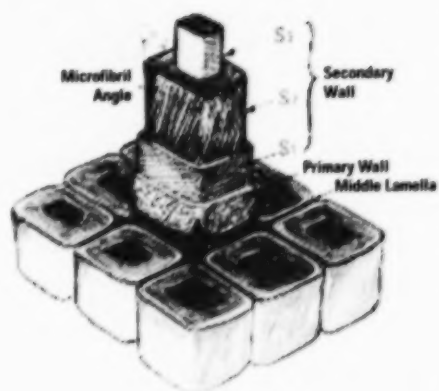


Wood fibres from U.V. (ultraviolet) exposure damage from sunlight.



71-year-old open-grown
lodgepole pine.

Wood Quality... Impact on Product Yields, Grades and Value.



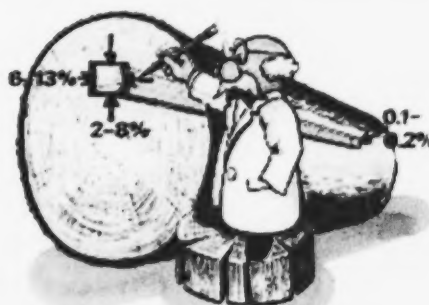
Wood Quality... Impact on Product Yields, Grades and Value.

Compression Wood



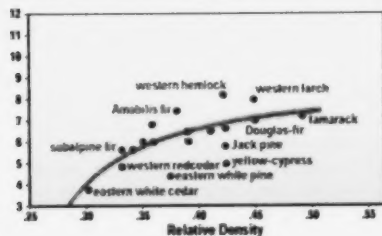
Wood Quality - Impact on Product Yields, Grades and Value

Typical Shrinkage Values for "Normal" Wood



Wood Quality - Impact on Product Yields, Grades and Value

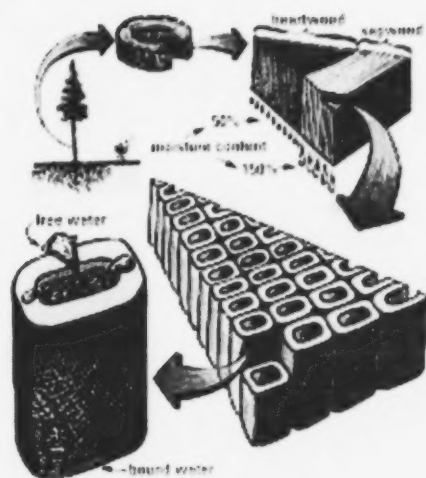
% Volumetric Shrinkage at 12% MC



Wood Quality... Impact on Product Yields, Grades and Value



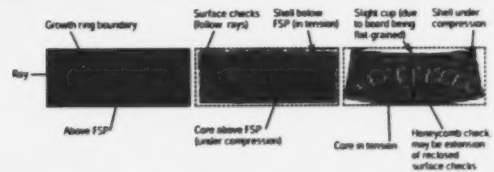
Wood Quality... Impact on Product Yields, Grades and Value



Wood Quality... Impact on Product Yields, Grades and Value

The Process of Wood Drying

Drying Stage:	I	II	III
Moisture Condition:	Above fibre saturation point (FSP) throughout. Drying begins with loss of free water from surfaces.	Shell now below FSP; core still above FSP. Core moisture migrates outward to shell.	Below FSP throughout, eventually reaches uniformly low EMC.
Stress Condition:	Stress-free	Shell tries to shrink, creates tension across surfaces, squeezes the core into compression. Drying sets shell in oversized condition.	Core now trying to shrink away from oversized shell. Core develops tension, pulls shell into compression.
Defects:	Defect-free	Surface may check; core may collapse.	Surface is casehardened; core may honeycomb.



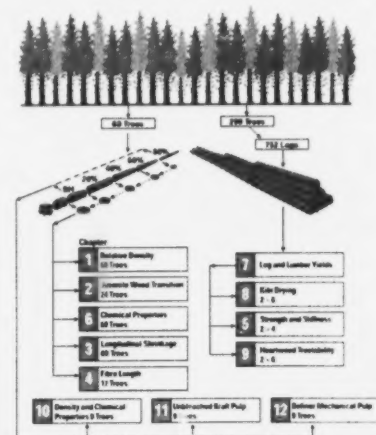
Wood Quality... Impact on Product Yields, Grades and Value

Continued on next page



Wood Quality... Impact on Product Yields, Grades and Value

Second Growth Douglas-fir Resource



Wood Quality... Impact on Product Yields, Grades and Value

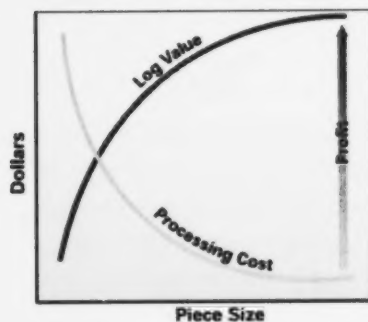
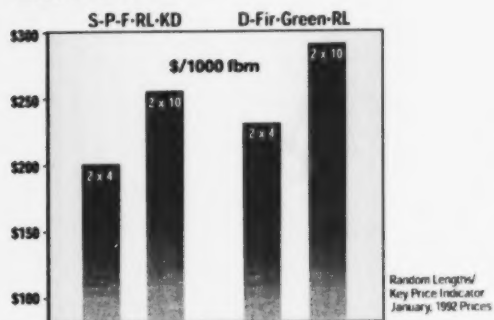


Good Quality... Invest in Product Tests, Copies and More

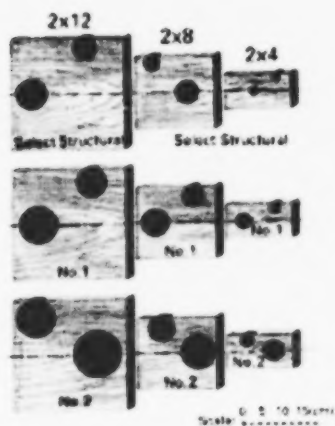


Wood Quality... Impact on Product Value, Grades and Value

Size Premium

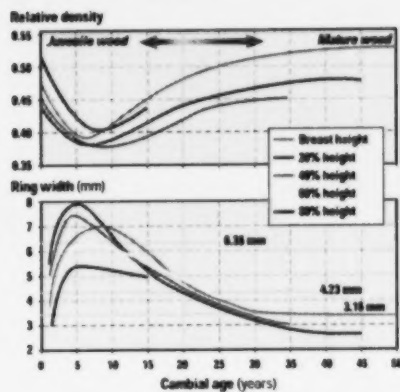


Wood Quality... Impact on Product Yields, Grades and Value
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Wood Quality... Impact on Product Yields, Grades and Value

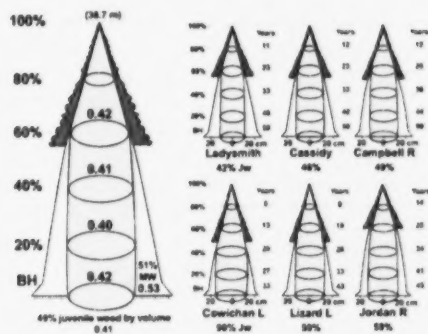
50-year-old Douglas-fir



Wood Quality - Impact on Product Yields, Grades and Value

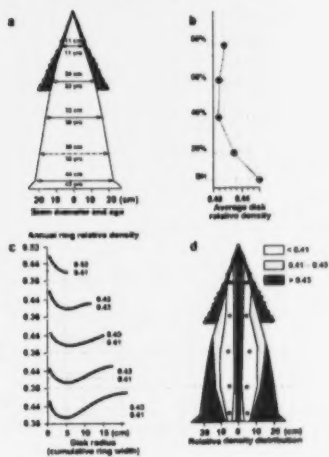
Juvenile Wood Cylinder

First 20 Years of Growth in 50-year-old Douglas-fir



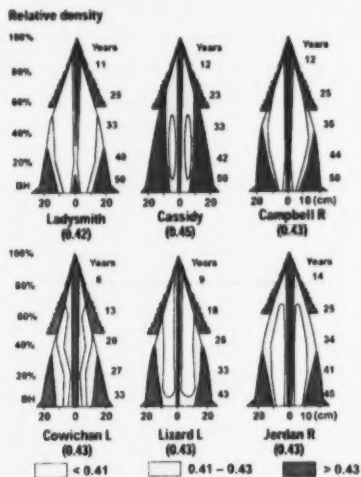
Wood Quality - Impact on Product Yields, Grades and Value

Diameter, Taper and Density Distribution in Douglas-fir



Wood Quality... impact on Product Yields, Grades and Value

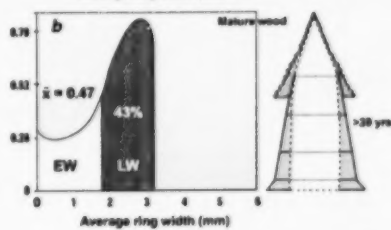
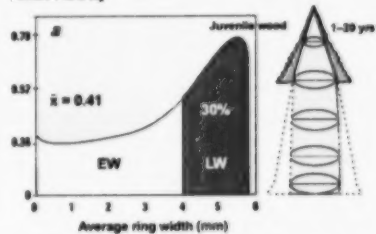
Relative Density Zones in Douglas-fir



Wood Quality... impact on Product Yields, Grades and Value

Juvenile/Mature Wood Ring Profiles

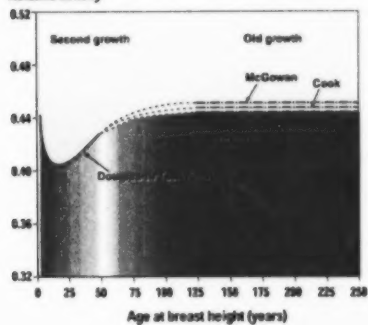
Relative density



Wood Quality... Impact on Product Yields, Grades and Value

Stem-wood Relative Density

Relative density



Wood Quality... Impact on Product Yields, Grades and Value

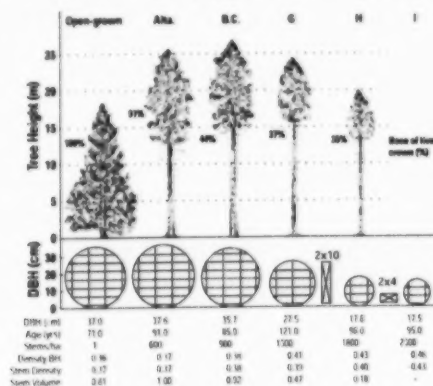
Conclusions:

- ◆ These 50-year-old Douglas-fir trees, growing at 530 stems/ha, contained 50% juvenile wood and 50% mature wood.
- ◆ At all height levels, the first 20 years of growth "defaulted" to juvenile wood because of wood density, fibre length, and longitudinal shrinkage.
- ◆ Juvenile wood is not useless wood.
- ◆ Larger knots permitted in wider widths.
- ◆ Challenge: find optimum between tree size and branch size at rotation age to maximise value, keeping future trends in mind.

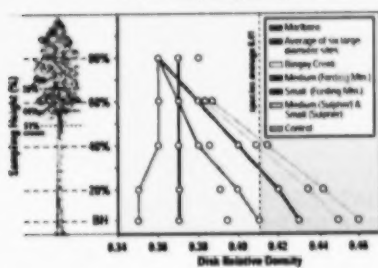
\$/ha/yr commercial forestry has to be profitable

- Other non-woody pressures on the land base - social forestry

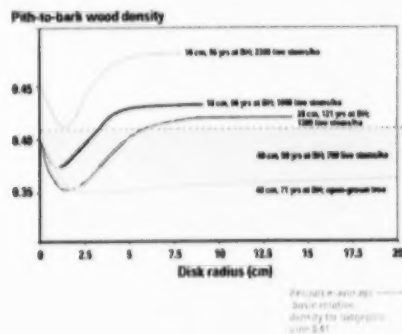
Average Dimensions of Small, Medium and Large Diameter Lodgepole Pine Task Force Trees

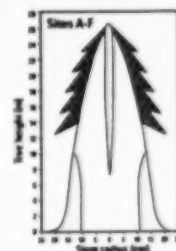


Average Disk Density at Five Sampling Heights



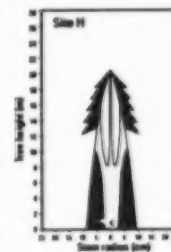
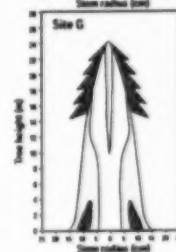
Pith-to-bark Wood Density and Tree-size Trends as a Function of Stand Density



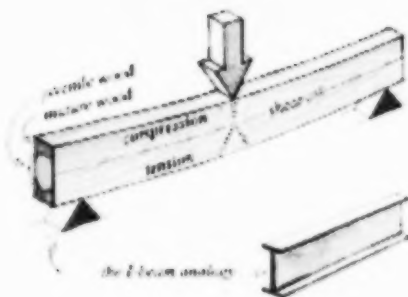
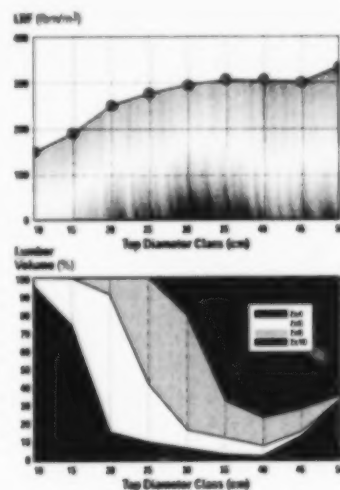


Second Growth
Lodgepole Pine
Density Distribution

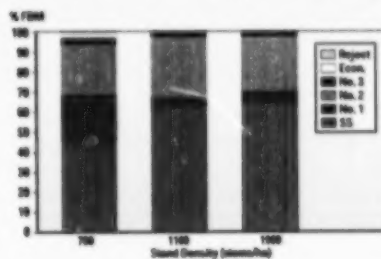
□ <.38
□ .38-.41
■ >.41



Wood Quality... Impact on Product Yields, Grades and Value

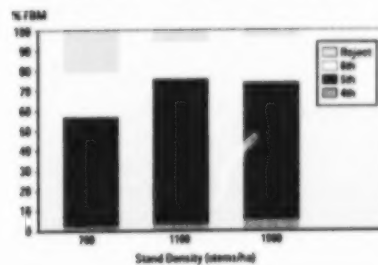


Structural Lumber Yields by Visual Grading



Wood Quality... Impact on Product Yields, Grades and Value

Door, Window and Furniture-Grade Lumber Yields by Visual Grading



Wood Quality... Impact on Product Yields, Grades and Value

MSR Summary

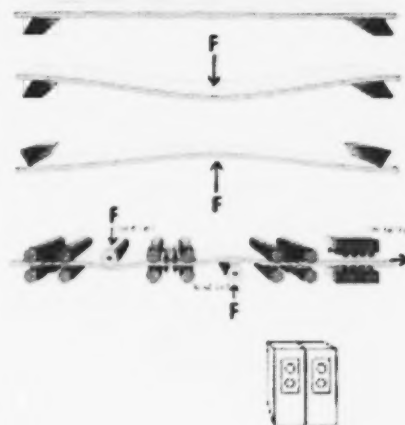
Uses of MSR Lumber

- Primary for roof trusses, I-joists, laminating stock for glulam
- Parallel chord floor trusses – new market (ease of handling, longer spans, ready openings for wiring, plumbing and ductwork)

Advantages of MSR Lumber

- better consistency because of E rating (more uniform "links")
- quality control in the plant – none with visually graded
- lumber can be cut from small logs (no need for very wide widths)
- reduced variability = reliability and exactness
- reduced waste (2% vs 10%)
- uniformity across "species boundaries" (fewer grades)
- Profit (marketability)

MSR Grading System



Wood Quality... Impact on Product Yields, Grades and Value

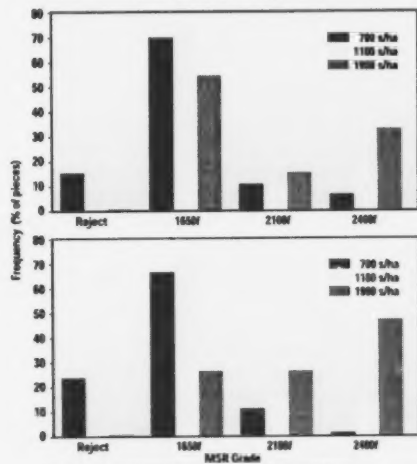
Strength of wood

is the resistance to forces deforming it.

- There are still other things besides relative density that affect the strength of wood.
- These include knots, slope of grain, compression wood, the relative amounts of earlywood and latewood, moisture content, temperature (above 65°C), and fibril angle (the part of the tree, near the pith, or farther out from which the piece was cut).
- A few basic terms in wood mechanics:
 - force:** push, pull and shear
 - stress:** force per unit area (psi)
 - strain:** unit deformation
 - stiffness (elasticity):** stress/strain
 - creep:** continuously stressed in bending, "flow", "sag"
 - fatigue:** loss in wood property due to repeated force application (bending back and forth, 1/3 max. stress, 30,000,000 times)

Wood Quality... Impact on Product Yields, Grades and Value

Machine-stress rated lumber yields
Distribution of MSR Grades for 2x4's by Stand Density

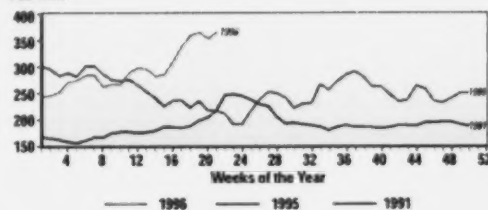


Distribution of MSR Grades for 2x6's by Stand Density

Wood Quality... Impact on Product Yields, Grades and Value
Source: Forest Sciences Centre of Canada, 2002

Western SPF KD Std&Btr Random Lengths - 2x4

US Funds -
FOB Mill



As reported by Madison's Canadian Lumber Reporter - May 24, 1996

MSR Lumber—Kiln Dried—8'/20'

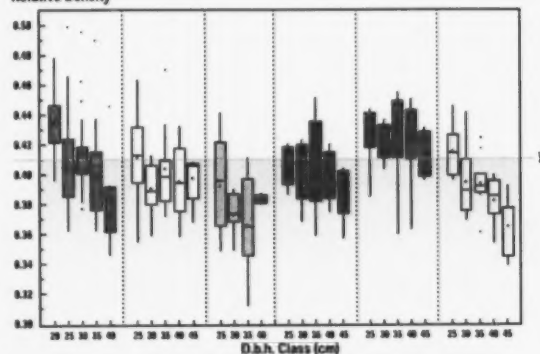
	2x4 SPF			2x6 SPF	
1650f	\$490	(450)		\$440	(400)
1800f	495	(455)		n/a	n/a
2100f	495	(460)		465	(425)
2400f	520	(480)		480	(440)

*Prices are in U.S. funds, F.O.B. Chicago
Prices in () are f.o.b. Vancouver

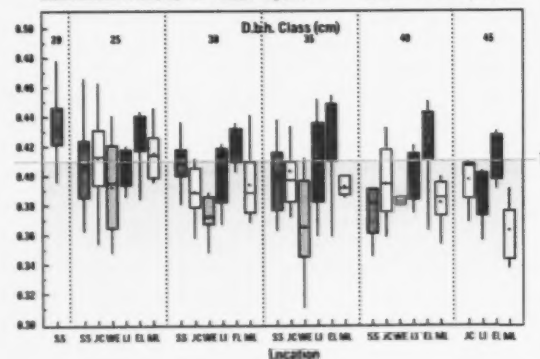
As reported by Madison's Canadian Lumber Reporter

Wood Quality... Impact on Product Yields, Grades and Value
MAY 24, 1996

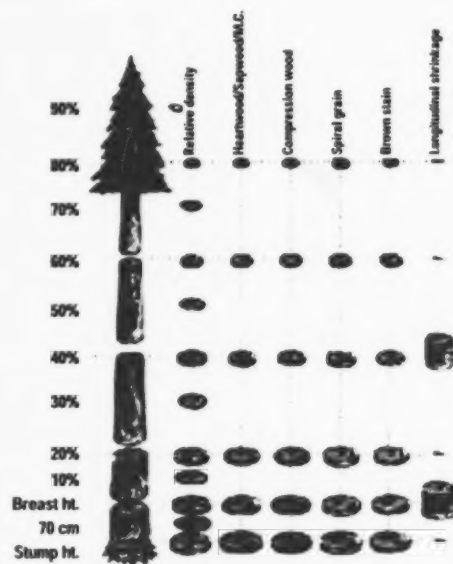
Breast Height
Relative Density



Sulphur Springs (MS) = SS Wells (ESSF) = WE Elbow Lake (OCH) = EL
 Jamieson Creek (MS) = JC Liberty (EDF) = LI Modeste Lake (SBS) = ML



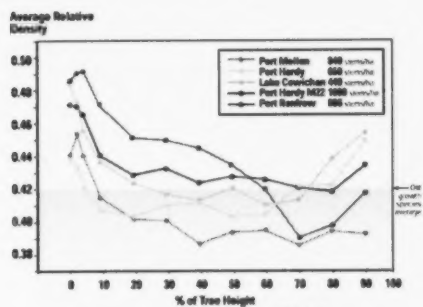
Wood Quality—Impact on Product Yields, Grades and Value
LOGCAMP FIRE COMBINATION STUDY



Sampling plan for basic wood properties characterization of second-growth western hemlock.

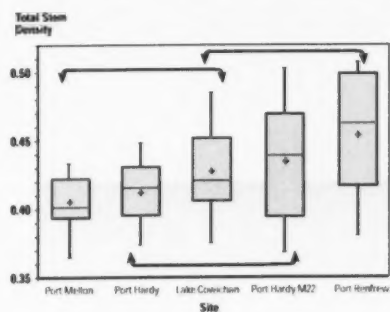
Wood Quality—Impact on Product Yields, Grades and Value
 ANNOTATED VERSION OF THE WOOD QUALITY FACT SHEET

Second-growth Western Hemlock Disk Densities at 12 Heights for Five Sites



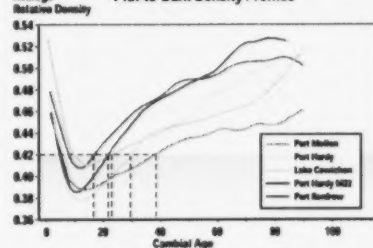
Wood Quality... impact on Product Yields, Grades and Value

Second Growth Hemlock – Total Stemwood Density Distribution

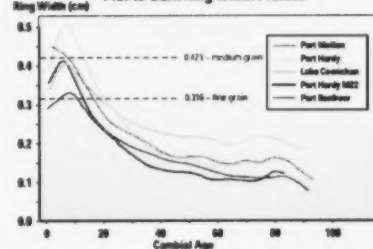
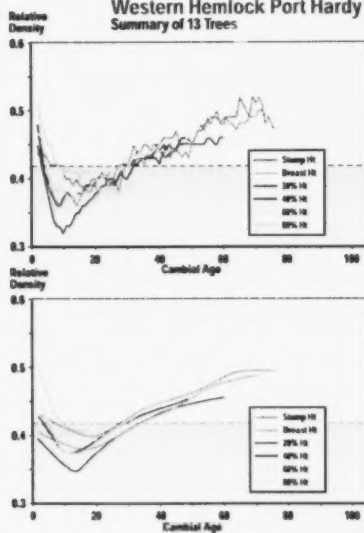


Wood Quality... impact on Product Yields, Grades and Value

Pith-to-Bark Density Profiles

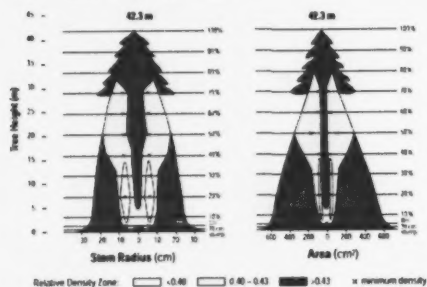


Pith-to-Bark Ring Width Profiles

Western Hemlock Port Hardy
Summary of 13 Trees

Lake Cowichan

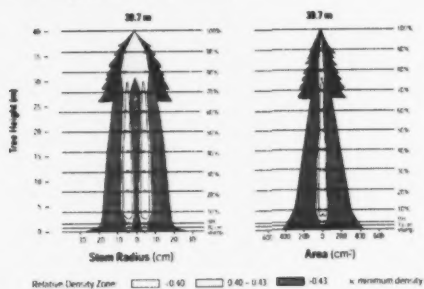
Summary of 13 trees (450 stems/ha)



Wood Quality... Impact on Product Yields, Grades and Value

Port Hardy M22

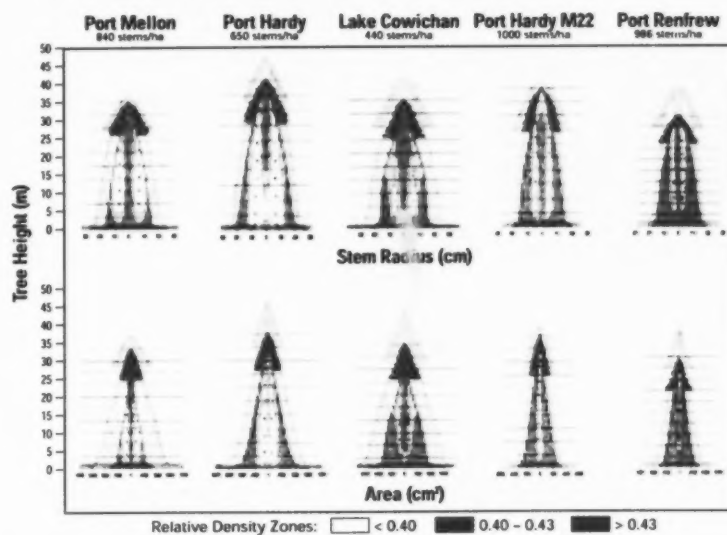
Summary of 13 trees (1000 stems/ha)



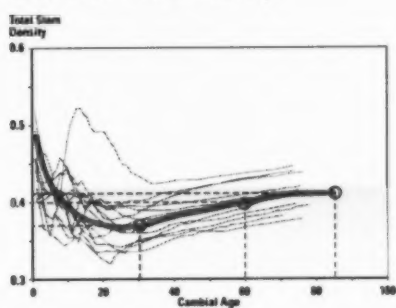
Wood Quality... Impact on Product Yields, Grades and Value

Average Tree Stem Profiles and Density Distributions

(summary of 13 trees per site at age 60 superimposed onto 90 year old trees)

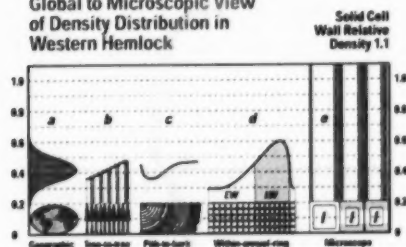


Western Hemlock Port Hardy



Wood Quality - Impact on Product Yields, Grades and Value

**Global to Microscopic View
of Density Distribution in
Western Hemlock**



Wood Quality - Impact on Product Yields, Grades and Value
© 2000 Weyerhaeuser Company

Western Hemlock

Log Grade	Old-growth	Second-growth
small D log length	\$ 10,000	\$ 4,000
12 - 16 in. H 16 - 24	12,000	8,000
15 - 16 in. I 12 - 14	12,000	15,000
4 - 11 in. J 16 - 24	5,000	20,000
4 - 14 in. X 8 - 12	6,000	4,000
15 - 16 in. Y 8 - 12	5,000	4,000
4 - 16 in. V 8 - 12	5,000	4,000
Total	\$ 50,000	\$ 55,000

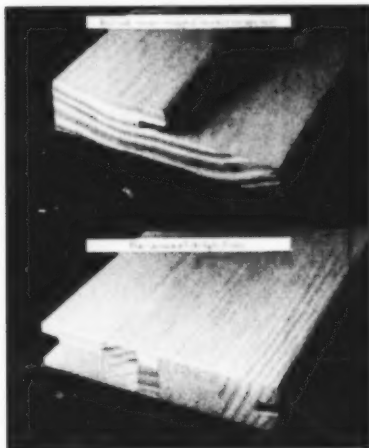
• Stand volume in second-growth 150 - 200m³
higher than in old-growth

WSP - North Vancouver Island

Wood Quality - Impact on Product Yields, Grades and Value
© 2000 Weyerhaeuser Company

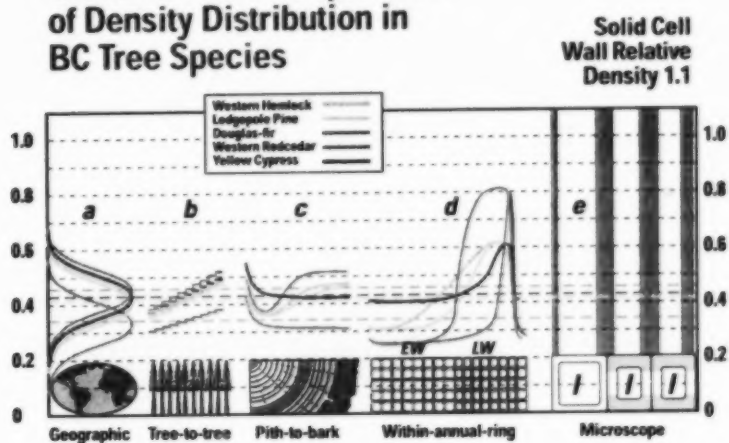


Wood Quality - Impact on Product Yields, Grades and Value

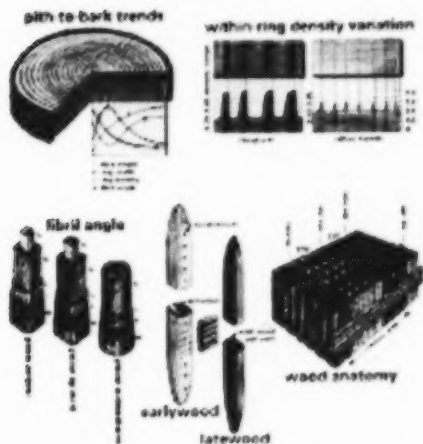


Wood Quality - Impact on Product Yields, Grades and Value

Global to Microscopic View of Density Distribution in BC Tree Species



...Tree, Log, Lumber and Fibre Characteristics



Wood Quality is Related to Measurable Stand...

